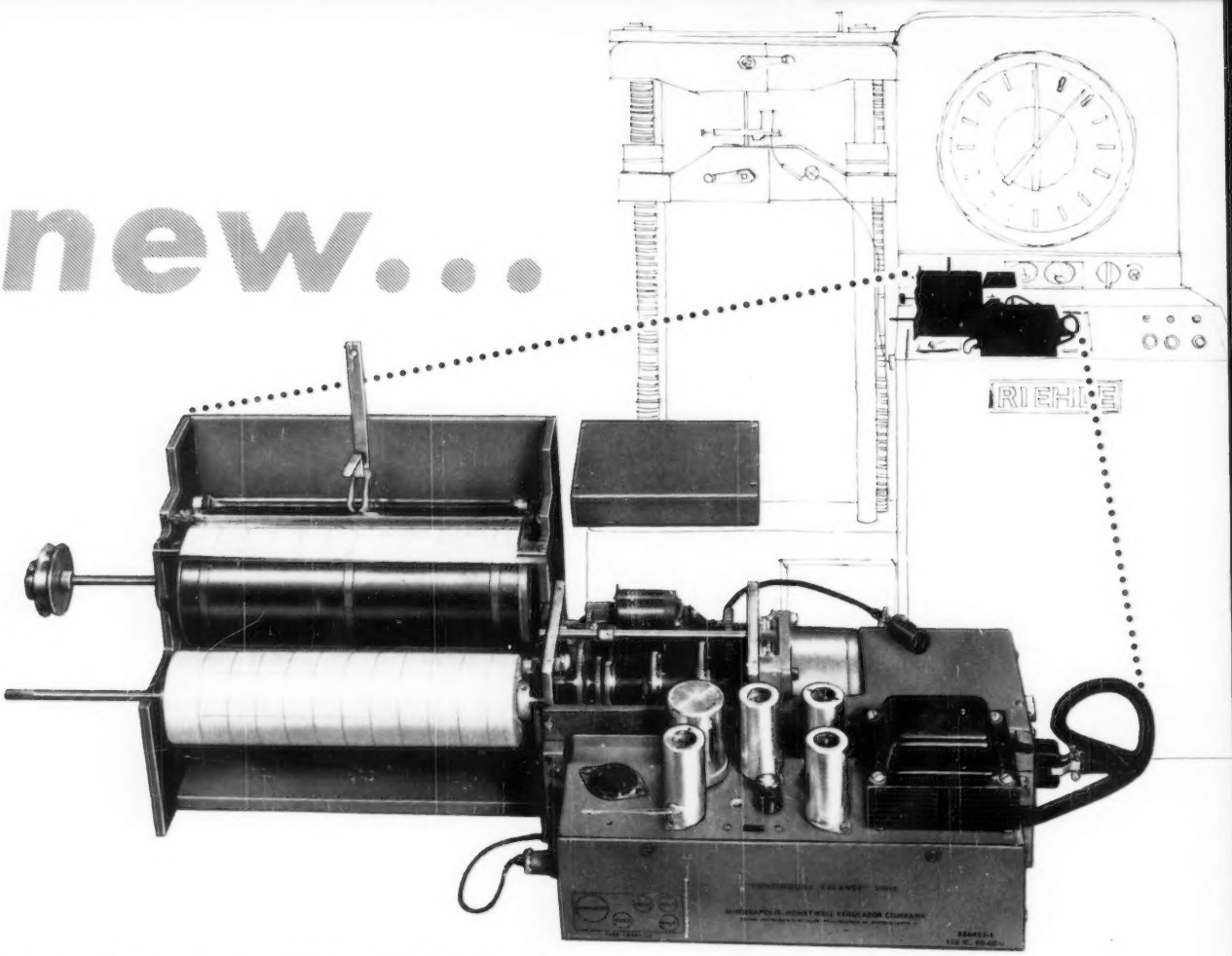
OCTOBER, 1957
No. 225

ASTM Bulletin

ASTM BOOKS IN 1957–58
A preview of the huge
Technical Publication program

American Society for Testing Materials

new...



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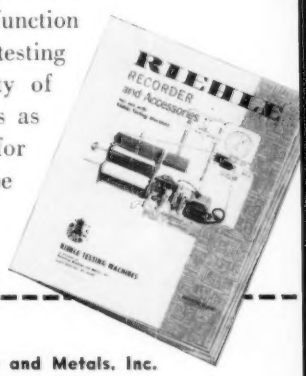

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OCTOBER 1957

Number 225

Telephone: Rittenhouse 6-5315 Cable Address: Testing, Philadelphia

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ASTM Bulletin, October 1957. Published eight times a year, January, February, April, May, July, September, October, and December, by the American Society for Testing Materials. Publication Office—20th and Northampton Sts., Easton, Pa. Editorial and advertising offices at the headquarters of the Society, 1916 Race St., Philadelphia 3, Pa. Subscriptions, United States and possessions, one year, $2.75, two years, $4.75, three years, $6.50; Canada, one year, $3.25; two years, $5.75, three years, $8.00. Other countries, one year, $3.75; two years, $6.75; three years, $9.50. Single Copies—50 cents. Number 225. Entered as second class matter, April 8, 1940, at the post office at Easton, Pa., under the act of March 3, 1879.

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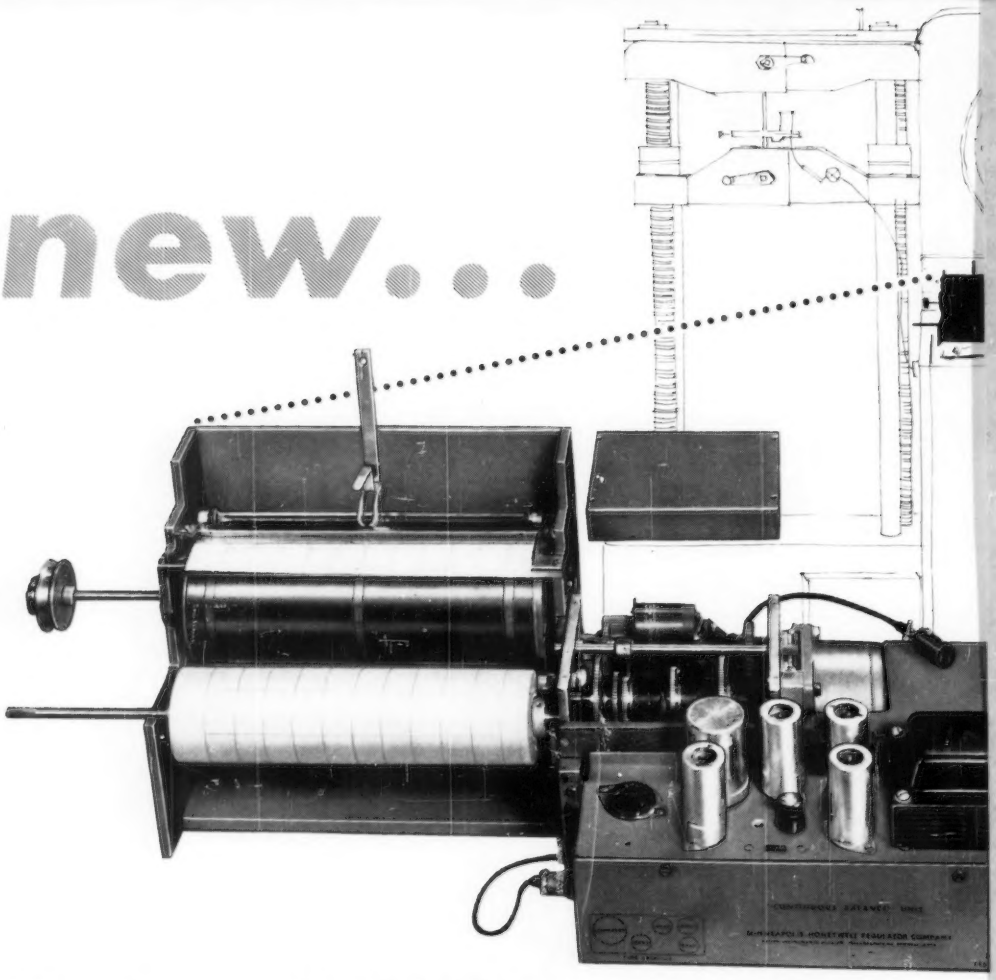

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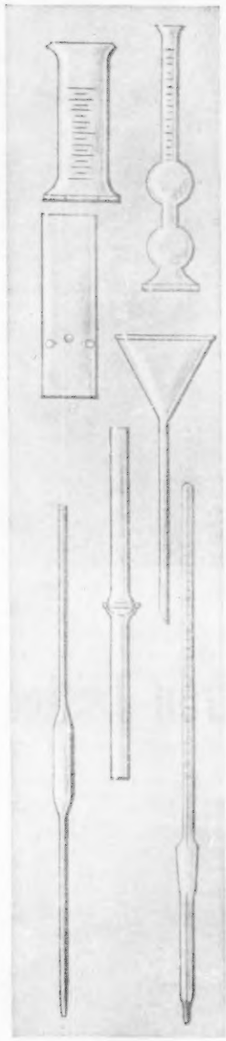

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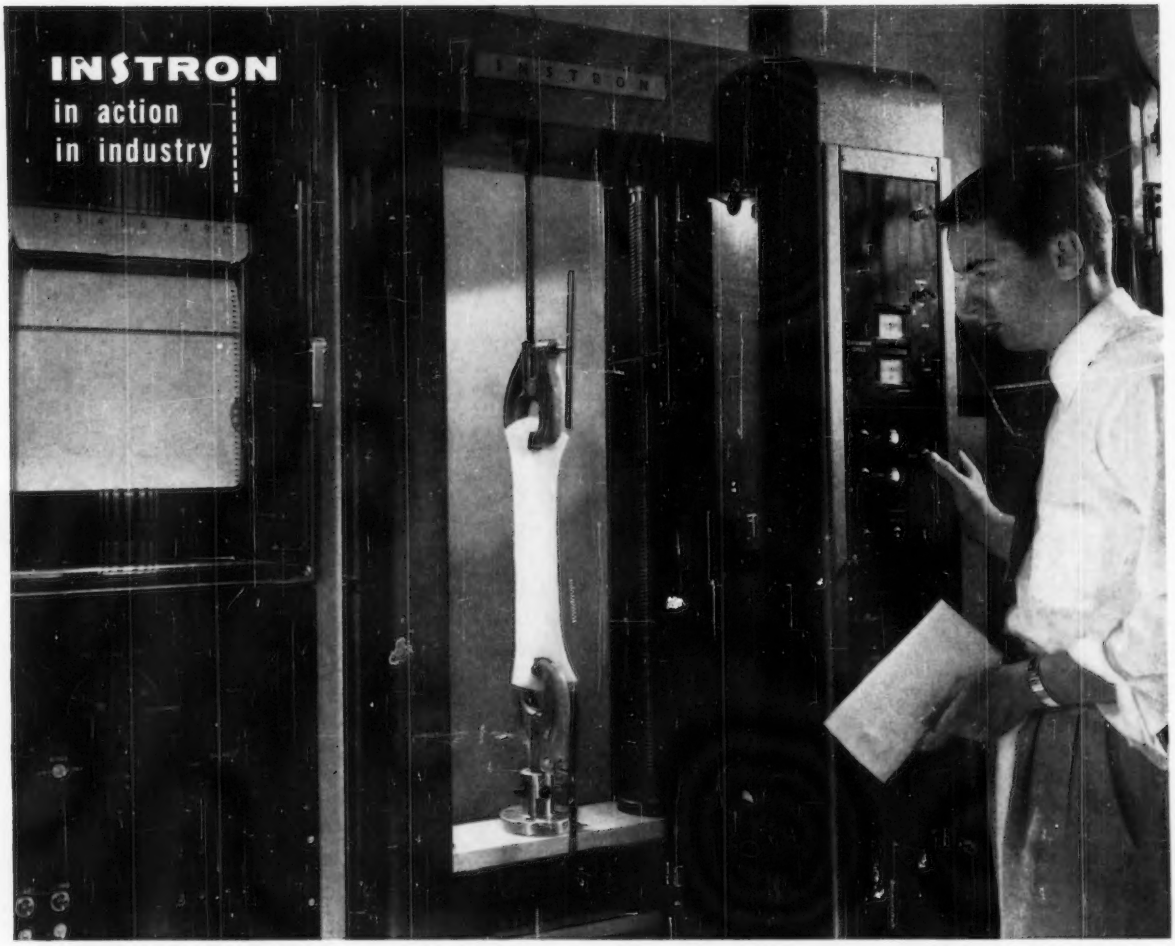

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ASTM BOOKS in 1957–58

Regular Publication Program Swelled by West Coast Meeting Papers

The ASTM publications scheduled to appear within the coming year are the crystallization of the Society's recent activities. The volume of publication which continues to grow from year to year was swelled this year by about 200 papers from the Second Pacific Area National Meeting held in September, 1956. Some of these Pacific Area papers have been published in the ASTM BULLETIN but most of them appear in 18 separate technical publications. The following pages give more detailed information concerning these publications, grouped roughly in related fields of interest.

The special technical publications which contain the symposia and papers contribute greatly to that phase of the Society's work concerned with the promotion of the knowledge of materials. The 1957 Supplements to the Book of Standards and the numerous special compilations of related standards reflect the growth in work and the concentration on the Society's second objective—standardization of specifications and tests.

Members will be advised of the appearance of these publications. As books become available, notices will appear in the BULLETIN. On most of the publications, special prices to members are in effect. Publications that are available are so indicated.

Regular Publications . . .

1957 Supplements to 1955 Book of Standards

The plan of issuing the Book of Standards triennially marks 1956 and 1957 as Supplement years. The 1957 Supplements to the 1955 Book of Standards will be issued in seven parts in heavy paper covers. They will include the new and revised standards and tentatives adopted or accepted at the 60th Annual Meeting or by the Administrative Committee on Standards, and will total some 2300 pages. The seven parts are:

1. Ferrous Metals
2. Non-Ferrous Metals
3. Cement, Concrete, Ceramics, Thermal Insulating, Road Materials, Soils
4. Paint, Naval Stores, Wood, Cellulose, Wax Polishes, Sandwich and Building Constructions, Fire Tests
5. Fuels, Petroleum, Aromatic Hydrocarbons, Engine Antifreezes
6. Plastics, Electrical Insulation, Rubber, Electronics
7. Textiles, Soap, Water, Paper, Adhesives, Shipping Containers, Atmospheric Analysis

Parts 2 and 6 are now in press. All parts are expected to be available by the beginning of the year.

Compilations of Standards

So many factors affect the release of these books that it is not possible to give an accurate estimate of their size or the date they will become available. The size is affected by committee recommendations which may be submitted through the Administrative Committee on Standards, and the date of issue is governed somewhat by editorial considerations and the relation of these special compilations to the appearance of the supplements to the Book of Standards. The tabulation given below of special compilations therefore should be viewed as approximate.

1957 Index to ASTM Standards

As the number of published ASTM standards grows, this Index increases in value. Providing the latest complete reference to the publications in which the various specifications and test methods appear, it is particularly useful during the years in which the supplements to the Book of Standards are issued. Publication of the new edition is scheduled for February.

Year Book

The Year Book, which will be available shortly, contains a list of complete membership and official company-member representatives (name, title, address, company, etc.), personnel of all ASTM committees, geographical listing of the membership, as well as other useful information about the Society. It is furnished to members free of charge on request and may be purchased by committee members.

1957 Proceedings

The 1957 *Proceedings* to be issued early next year will contain approximately 1500 pages of technical papers and discussion presented at the 1957 Annual Meeting. The discussions comprise a most significant and technically valuable feature of

STANDARDS COMPILATION SCHEDULE.

Sponsoring Committee	Title	Approximate Number of Pages	Approximate Appearance Date
A-1	Steel Piping Materials	470	February
A-3	Cast Iron	138	December
B-1	Wires for Electrical Conductors	320	November
B-5	Copper and Copper Alloys, Cast and Wrought	688	September
B-7	Light Metals and Alloys, Cast and Wrought	300	December
C-8	Refractories	410	November
C-11	Gypsum	148	September
C-14	Glass and Glass Products	150	October
D-1	Paint, Varnish, Lacquer and Related Products	900	January
D-2	Petroleum Products and Lubricants	1140	November
D-3	Gaseous Fuels	184	January
D-5	Coal and Coke	142	September
D-6, D-10	Paper and Paper Products and Shipping Containers	420	November
D-9	Electrical Insulating Materials	688	October
D-12	Soaps and Other Detergents	180	September
D-13	Textile Materials	840	November
D-14	Adhesives	250	November
D-15	Engine Antifreezes	60	January
D-18	Testing Soils	584	November
E-2	Emission Spectroscopy	508	October
F-1	Materials for Electron Tubes and Semiconductor Devices	130	December
	Building Code Standards	972	February
	Sampling of Petroleum	168	November

the *Proceedings*. All reports submitted by the Society's technical committees at the Annual Meeting are also included.

The Gillett and Marburg Lectures are issued as separate publications and no longer appear in the *Proceedings*. Copies, however, are available to members on request.

The papers and discussions presented at the Annual Meeting as part of special symposiums will appear in special technical publications.

Metals . . .

A Perspective of Molybdenum-Base Alloys—1957 Gillett Lecture*

By Alvin J. Herzig

The sixth Gillett Memorial Lecture was presented by Alvin J. Herzig, president, Climax Molybdenum Co. of Michigan, on "A Perspective of Molybdenum-Base Alloys." This lecture is jointly sponsored by ASTM and Battelle Memorial Inst. and commemorates Horace W. Gillett, the first director of Battelle and one of this country's leading metallurgists.

The potential of molybdenum as an alloy-base metal has been in development since the beginning of the century. Because of its high melting point, it was extremely difficult for many years to obtain the elemental metal in section sizes which would make it attractive as an engineering material. By the 1930's through development of powder metallurgy processing, a small but significant application of molybdenum in the electronics field has been established. The knowledge of the metal thus gained provided impetus for the investigation of methods to produce larger sections of molybdenum when in the early 1940's it became apparent that our developing technology would require super high-strength materials in the future. The development of a commercially feasible vacuum arc-casting process by the late 1940's made it desirable to re-examine the potential strength of the system of molybdenum-base alloys.

In this lecture, the author attempts to give a perspective of the broad subject not only by reciting some of the properties which have already been achieved in molybdenum-base alloys but also by speculation in some of the areas where complex, technical problems still remain.

Since the Gillett Lecture is no longer included in the *Proceedings*, the lecture, with self covers, is available free of charge to ASTM members on request. This publication is now available. Copies with special covers, may be obtained by members for $1. Nonmembers may procure copies for $1.25.

Symposium on Titanium STP 204†

Sponsored by Committee B-2 on Non-Ferrous Metals and Alloys and Administrative Committee on Research

High interest and the exceptional rate of progress in working out the technology of titanium has resulted in an amazing number of technical papers, symposia, and special meetings to cover this progress. Because of this excellent coverage by other societies ASTM has hesitated to organize technical sessions until a real need existed. Such a need was shown first by interest in specifications. As problems arose showing the need for good technical information on which to base specifications, it appeared desirable to encourage technical papers along testing and property evaluation lines. Although a number of papers submitted for this symposium have not dealt directly with test procedure they have been included as being of particular interest.

This 190-page publication is now available. Price $4.75; to members, $3.50. (A more detailed review of this book appears in the September issue of the ASTM BULLETIN.)

Symposium on Determination of Gases in Metals STP 222*

Sponsored by Committee E-3 on Chemical Analysis of Metals

This symposium is designed to review the present status of the determination of gaseous elements, particularly oxygen, in metals. Vacuum fusion analysis has been used for many years for gaseous elements in steel and alloys, but the apparatus was complex and fragile; and the analysis so time-consuming that it was seldom made except for the guidance of research work. With the advent of reactive metals such as titanium and more stringent specifications for other metals—for example, electronic grade nickel—interest in this determination has increased greatly.

In one of the papers a versatile vacuum fusion apparatus is described and the use of metal bath techniques as well as an apparatus for the rapid determination of hydrogen. In another paper the importance of vacuum fusion is shown by projecting a study of nickel from ingot to the finished product. A third paper covers oxygen determinations using a platinum bath and capillary trap. In the fourth paper, the principles of the bromination-carbon reduction method for the determination of oxygen in metals and an improved and simplified apparatus are discussed. The problems encountered in extending emission spectrometric methods to the determination of the oxygen content of metals are covered in the final paper, and several techniques for surmounting some of these problems are discussed.

Papers on Metals STP 196†

This special technical publication on metals contains most of the papers presented at three of the sessions held at the Second Pacific Area National Meeting, namely, those from the Fatigue, Ferrous Metals, and Non-Ferrous Metals Sessions. The titles of these papers are as follows:

Studies of Stainless Steel Columns Subject to Compression Loads
Shotpeening Effects and Specifications
Effect of Forming on Mechanical Properties
Axial Stress Fatigue, Creep, and Rupture Properties of Unnotched Specimens of Heat Resistant Alloys
Determination of Young's Modulus Under Conditions of Relaxation
Effect of Number of Variables on the Fatigue Properties of High Strength Steels
Effect of Temperature, Frequency and Grain Size on the Fatigue Properties of High Purity Aluminum
Determination of Fatigue-Crack Initiation and Propagation in a Magnesium Alloy
Uni-Directional Axial Tension Fatigue Tests of Beryllium Copper and Several Precipitation Hardening Corrosion Resistant Steels
The Properties of Beryllium Copper Strip as Affected by Cold Rolling and Heat Treatment
Pit Depth Measurements as a Means of Evaluating the Corrosion Resistance of Aluminum in Sea Water

Compilation of Chemical Compositions and Rupture Strengths of Super-Strength Alloys STP 170A

Sponsored by Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys—Prepared by W. F. Simmons and V. N. Krivobok

This up-to-date compilation on superstrength alloys, a revision of an earlier publication, lists the names, nominal chemical composition, characteristic rupture strengths for rupture in 100

* Presented at the 1957 Annual Meeting in Atlantic City, N. J., June 16–21, 1957.

† Presented at the Second Pacific Area National Meeting in Los Angeles, Calif., September 17–21, 1956.

and 1000 hr, and patentees for approximately 150 domestic and 75 foreign alloys. Included in this revised edition are the ferritic (martensitic) super-strength alloys and age-hardening stainless steels. The data, obtained from all possible sources, are arranged in easy-to-read tabular form.

This publication is now available. Price: $0.75. (A more detailed review of this publication appears in the September issue of the ASTM BULLETIN.)

1957 Supplement to the Metal Cleaning Bibliographical Abstracts STP 90 D

Sponsored by Committee D-12 on Soaps and Other Detergents—Prepared by J. C. Harris

The present supplement contains over 225 new references. The inclusion of early United States patents extends the coverage of this phase of the literature to make it as nearly complete as possible. This book supplements the previous editions (*STP 90B, STP 90C*) so that the years 1842 through 1956 are rather thoroughly covered.

In order to facilitate reference to the abstracts, they have been thoroughly indexed by subject, author, specification, and patent. Wherever possible, original articles have been abstracted. However, for a field of such dimensions, liberal use has been made of abstract journals, and where such a journal appears as the last reference in an abstract, this has been the source of the present information.

The general fields covered are practical application, laboratory evaluation, theory, and references from other fields applicable to the subject. While it is understood that cleaning is the general field covered in the index, such subjects as "Chemical Cleaning" of boilers and other "in place" apparatus has become a recognized term, and is used in this manner here, though pickling, etch, or fused bath treatments are fully as "chemical" in effect.

This bibliography should prove valuable to those who must maintain boilers, whether stationary or mobile; heat exchangers; to the corrosion engineer; dairy cleaning; paper mill machinery maintenance; automotive cleaning; tanker cleaning; and those who develop special equipment for the multitude of cleaning jobs.

Coverage is given for fields of recent interest such as cleaning of stainless steels, cleaning the recently introduced metals such as titanium; and cleaning semiconducting elements such as germanium and silicon.

This 44-page book is now available. Price: $2; to members, $1.50.

Symposium on Structural Sandwich Construction STP 201†

Sponsored by Committee C-19 on Structural Sandwich Construction

This symposium was sponsored with the expectation that it will better acquaint the industry with what is being accomplished in the way of standardization of test methods and also to inform all those interested of the progress that has been made, and to act as a "sounding-board" as to what lines of endeavor need further emphasis. The testing of materials and the application of sandwich construction are discussed in ten papers. High-temperature testing is dealt with in several papers, this being one of the critical factors in aircraft structural application. Two papers discuss adhesive bonds, including metal-to-metal and metal-to-plastic adhesion.

This 105-page publication is now available. Price: $2.75; to members, $2. (A more detailed review of this book appears in the May issue of the ASTM BULLETIN.)

The Elevated-Temperature Properties of Weld-Deposited Metal and Weldments STP 226

Prepared by H. R. Voorhees and J. W. Freeman for Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals

The Subcommittee on the Properties of Weldments of the Data and Publications Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals accumulated data from laboratories conducting tests at elevated temperatures on welds. The original data were in the form of reports, technical papers, and a questionnaire circulated by the subcommittee. These data have been reduced to a common type of data sheet and the key properties presented graphically as a function of temperature. The approximate ranges in properties for the unwelded forms of the alloys, as presented in prior Special Technical Publications of the ASTM, are shown to indicate the relative properties of welds and base metals.

Data are presented for carbon, low-alloy, and austenitic steels and for a number of the complex alloys developed for high strength at high temperatures. Tensile, rupture, and creep properties are covered by the data. The data sheets provided space for information on the welding methods and conditions, chemical composition of both base metal and weld deposit, heat treatment, hardness, and microstructural characteristics. Both original test data and derived creep and rupture strengths are shown on the data sheets. The source of data is acknowledged on each data sheet. In most cases only part of the data for which provision was made in the data sheets was available.

Properties were reported for specimens taken entirely from weld-deposited metal as well as for cross-weld specimens which included both base metal and weld deposit in the gage section. In cross-weld specimens the weld deposit frequently differed in composition from the base metal; and in some cases two different base metals were present in the same weldment. Some data covered sheet specimens welded without filler metal.

1956 Supplement to the Bibliography and Abstracts on Electrical Contacts STP 56 K

Sponsored by Committee B-4 on Metallic Materials for Electrical Heating, Electrical Resistance and Electrical Contacts—Prepared by Erle I. Shobert II

This is the fourth supplement published to the 1952 edition indicating that the work is continuing at a high level of activity. Its publication makes it possible for everyone concerned with electrical contacts to keep currently up to date with the latest information. The Subject Index lists the same headings as were given in the 1952, 1954, and 1955 editions, namely, electric contacts—general; contact materials—fabricated; contact materials—powdered metals; circuit breaker design; circuit breaker testing; contactor or relay design; stationary or fixed contacts; sliding contacts—slip ring; sliding contacts—commutation; miscellaneous special applications; contact resistance; electric arc theory applied to contacts; electric arc theory; glow discharge theory; spark discharge theory; contact wear; and circuit and circuit parameters as applied to contact operation.

The 40-page publication is now available. Price: $1.75; to members, $1.35.

Nuclear Energy . . .

Symposium on Radiation Effects on Materials (Vol. I) STP 208†

Sponsored Jointly by Committee E-10 on Radioisotopes and Radiation Effects and the Atomic Industrial Forum

This symposium is divided into three categories: (1) theory of radiation, (2) radiation facilities and mechanics of testing, (3) experimental tests and results on fuel and graphite materials and structural materials, including organics. The data and evaluations presented are a contribution to the understanding of existing code and specification values as they apply to nuclear reactor structures and components.

This 196-page publication is now available. Price: $4.75; to members, $3.50. (A more detailed review of this book appears in the July issue of the ASTM BULLETIN.)

(Vol. II) STP 220*

The importance of this subject and the interest shown in the Symposium on Radiation Effects on Materials (Vol. I) *STP 208* which was presented at the Second Pacific Area National Meeting in September, 1956, indicated the desirability of holding additional ones, perhaps on an annual basis. Consequently the same groups sponsored this second symposium.

The symposium was organized with two papers dealing with the influence and use of radiation effect information on reactor design consideration, five on facilities and techniques involved in radiation studies, and five on radiation studies of specific materials of interest to reactor design. The resulting symposium should fill these objectives.

The titles of the papers comprising the symposium are as follows:

Systems Consideration Affecting Selection of Structural Materials for Nuclear Power Plant Components
Problems in Standardization of Techniques in Radiation Studies
Application of the Battelle Research Reactor to Radiation-Effects Studies
A Technique for Measurement of the Electrical Resistivity of Radioactive Metals
Techniques of Tension Testing of Irradiated Materials at Elevated Temperatures at Hanford
Hanford Atomic Product Operation's Improved Remote Metallographic Equipment
Techniques for Making Visual Examinations and Dimensional Measurements at Hanford's Radiometallurgy Laboratory
Effect of Heat Treatment and Burnup on the Radiation Stability of Uranium-10 w/o Molybdenum Fuel Alloys
Engineering Effects of Radiation on Nuclear Fuels
A Survey of the Radiation Stability of Hydrocarbon Fuels
Selection of Organic Materials as Reactor Coolant-Moderators
Effects of Radiation on Electronic Components—I. Semiconductor Devices

Symposium on Radioisotopes STP 215†

Sponsored by Committee E-10 on Radioisotopes and Radiation Effects

Committee E-10 was created some years ago to be of service to other ASTM groups as an advisor in the rapidly changing atomic energy scene. It has been one of the primary objectives of this committee to bring such thought-provoking and educational information before the general membership of ASTM. This symposium represents such an effort, and brings contributions from some of the prominent people in their respective fields.

The use of radioisotopes in industry is becoming legend, saving hundreds of millions of dollars each year in terms of process and product improvements and knowledge gained. The selection of symposium topics illustrates the amazing breadth of radioisotopic tracing. Case histories are presented ranging from electroplating studies, the evaluation of rubber deterioration, and the mechanism of detergency, to the analysis of trace materials by neutron irradiation and the achievement of process control via tracers during full scale petroleum refinery operations. The papers on precision industrial gaging of either moving or static solids and solutions will suggest to the reader a wealth of opportunities for future standards and useful applications. In addition, virtually all companies represented in ASTM will find the final two articles particularly stimulating, whether they manufacture a product destined for use in the nuclear reactor field or are simply interested in exploiting radiation *per se* to initiate new processes or alter the properties of an existing product. These provocative discussions are: "Will ASTM Standards Be Influenced by Radiation Effects in Metals?" and "The Problem of Establishing Specifications for Irradiated Organic Materials."

(For a publication on nondestructive tests in the nuclear energy field, see Nondestructive Testing on next page.)

Symposium on Large Fatigue Testing Machines and Their Results STP 216*

Sponsored by Committee E-9 on Fatigue

Most of the knowledge of fatigue that has been made available since Wöhler's pioneer work in 1870 has come from tests on relatively small specimens. Today, there is a marked tendency to carry out fatigue tests on actual components which has involved in many cases the testing of sections considerably larger than the conventional laboratory specimen. Since, prior to Wöhler, tests were conducted by Fairbairn on full-size wrought iron girders, in the utilization today of full-scale testing we are returning to the practices of some of our predecessors.

This extension of full-scale testing has necessitated the development of large size testing machines, and like all engineering developments, while the use of such machines has solved certain problems, it has also raised others. Notably, in this regard the testing of large specimens emphasizes the influence of a size effect on the fatigue strength of plain specimens.

The experimental difficulties connected with the fatigue testing of large specimens are considerable and the tests are expensive and time consuming. Furthermore, such effects as stress concentration and fretting corrosion of large-size sections may have a different relation to the basic strength than they have in small-size sections. These factors have led to the testing of specific large machine elements, but unfortunately the data secured have usually a limited application.

As a consequence of the paucity of available data the subject of size effect remains somewhat controversial, and it is hoped

OFFERS OF PAPERS FOR 1958

THE Administrative Committee on Papers and Publications will meet in early February to consider the papers to be published by the Society in 1958 and to develop the program for the Annual Meeting to be held in Boston, June 22–28.

All those who wish to offer papers for presentation at the meeting and publication by the Society should send these offers to Headquarters *not later than January 10, 1958.*

All offers should be accompanied by a summary which will make clear the intended scope of the paper and will indicate features of the work that will, in the author's opinion, justify its publication and inclusion in the Annual Meeting program.

Suitable blanks for use in transmitting this information will be sent promptly upon request to Headquarters.

that the papers included in this symposium, together with the discussion, will aid in the clarification of the role of size in fatigue besides furnishing information on new types of large testing machines.

Symposium on Fatigue with Specific Reference to Aircraft Structures STP 203†

Sponsored by Committee E-9 on Fatigue

This publication comprises five papers of interest to the aircraft industry. In one of the papers, a method of inspection and rehabilitation is described for aircraft structural joints which can reliably extend their safe service life. In another paper the results of fatigue tests and strain measurements on riveted joints are presented. One of the papers shows that the effect of stretching and bending on the mechanical properties of metals can be understood as the effect of three influences: strain hardening or cold work, micro-residual stresses, and macroresidual stresses. The subject of another paper is unidirectional axial tension fatigue tests of beryllium copper and several precipitation hardening corrosion-resistant steels. Full scale wing fatigue testing is the subject of the last paper which explains that the advantages of the distributed load type system with the resonate beam system will result in correct bending moment, shear, and torsion being applied over a great percentage of wing span; the cycle rate of the system will be high and the power consumed negligible. This report deals with the physical details of such a test currently being run at Convair. In the final paper, the fatigue strength evaluation of airframe structural sections and components is discussed with particular reference to development of test specifications and requirements for testing equipment.

Nondestructive Testing . . .

Symposium on Nondestructive Tests in Nuclear Energy Field STP 223

Sponsored by American Institute of Chemical Engineers, Nuclear Division; American Nuclear Society; American Society for Testing Materials; Society for Nondestructive Testing; and the Atomic Industrial Forum

It seems highly appropriate that ASTM is a sponsor of this symposium in view of the rather extensive ASTM efforts in this direction. Most of the forty or more papers included in this symposium have been recently declassified by the Atomic Energy Commission. The objective of this symposium is to reach people who are concerned with nondestructive testing, regardless of whether they are directly involved in the nuclear business. As a result of intense activity necessary to the development and construction of nuclear reactors, valuable information and methods in this field have been developed. The sponsoring societies arranged this symposium to disseminate the knowledge and also to enlist the sympathy of those not directly involved in nuclear energy development.

There are few, if any, other products which require the maintenance of such high standards as are required for a reactor. Insistence on these standards has, of course, cost a great deal of money. But it might have cost a great deal more to scrap a reactor because of premature failure. At this stage, therefore, effort is concentrated on reducing the cost of inspection without sacrificing product quality. Such efforts will naturally benefit industry in general as well as the atomic industry.

It seems worthwhile here to emphasize a concept which is becoming apparent. Engineers and scientists in the nuclear business have the same types of problems and apply the same methods to solve them as do their brothers in other technical enterprises. All use factors of safety involving a large or small factor of ignorance and a risk factor weighted against the consequences of failure. There is nothing inherently mysterious or unique about the nuclear business—it is just newer.

This symposium is designed to bring component suppliers and consumers and manufacturers of testing equipment closer together. There must be a meeting of the minds as to the necessity and real value of certain tests. (Other publications relating to nuclear energy appear under Nuclear Energy on page 8.)

Symposium on Nondestructive Testing STP 213†

Sponsored by Committee E-7 on Nondestructive Testing

The first six papers comprise reports by subcommittee officers on activities in the fields of radiography, magnetic-particle testing, and ultrasonics. Also included is an outline and history of the over-all committee work of Committee E-7. All papers emphasize that time and personnel do not permit many needed standardization projects to be assigned at present, and the hope is expressed that many people will participate even if only on a correspondence basis.

The second part of this symposium comprises eight papers all by recognized experts in the field of nondestructive testing. The subjects covered are development of technique for the detection of cracks in small cylindrical specimens by eddy current and reluctance methods; electronic X-ray image systems; recent developments in the use of ultrasonic attenuation and velocity measurements in the study of properties of materials; nondestructive testing on Southern Pacific Railroad; nondestructive testing of heavy metals; ultrasonic inspections of aircraft forgings; an ultrasonic technique for nondestructive evaluation of metal-to-metal adhesive bonds; and nondestructive testing of bonded metal sandwich materials.

Water . . .

Your Most Important Raw Material—Water 1957 Marburg Lecture*

By E. P. Partridge

The Edgar Marburg Lecture was established as a memorial to the first Secretary of the Society with the purpose of emphasizing the importance of furthering knowledge of properties and tests of engineering materials. At the 1957 Annual Meeting, the thirty-first Edgar Marburg Lecture entitled "Your Most Important Raw Material—Water" was presented by Everett P. Partridge, director, Hall Laboratories.

Water is as basic to industry as it is to life itself. Short in supply in various parts of the United States, water actually is plentiful over the country as a whole. Unlike our rapidly decreasing resources of minerals and fossil fuels, fresh water is supplied to us year after year as rain and snow at a rate approximately seven times our total use. Our problem is to catch it, store it, and transport it to the regions where we need it. Then we must use and reuse it efficiently.

Like most raw materials, water is contaminated with various substances that cause trouble. Some of these impurities are the natural result of flow over or through the surface of the earth. More and more, however, the wastes from our human activities have complicated the reuse of water.

What must be done to prepare water for industry depends on the way it is to be used. Ultra-pure water containing no more than 50 parts per billion of total impurities may be specified for a once-through boiler, while the effluent from a municipal sewage plant serves satisfactorily for cooling equipment in a great steel mill.

Symposium on Industrial Water and Industrial Waste Water STP 207†

Sponsored by Committee D-19 on Industrial Water

Although water for industrial use and for the disposal of waste has always been important, the rapid industrial and technological advances in the past few decades have made this one of industry's foremost problems. This symposium presents important contributions to the solution of some of the problems in this field.

This 56-page publication is now available. Price: $2; to members, $1.50. (A more detailed review of this book appears in the July issue of the ASTM BULLETIN.)

Symposium on Determination of Dissolved Oxygen in Water STP 219*

Sponsored by Committee D-19 on Industrial Water

The importance of dissolved oxygen in water used for biological and industrial processes does not diminish. Not only is it necessary to know the exact concentration at intervals, but in many processes unremitting vigilance must be maintained against momentary or periodic variations in this concentration. This symposium presents the best current information on methods and apparatus for determination of dissolved oxygen in water, both by manual spot-check or calibration and by instrumental continuous indication and record. The several papers discuss the principle, advantages, and disadvantages of their respective procedures and apparatus so that readers can select those most appropriate for their specific needs.

The titles of the five papers are:

Study of the Accuracy of Methods of Testing for Dissolved Oxygen in High-Purity Water
Polarographic Measurement of Dissolved Oxygen
The Beckman Oxygen Analyzer
Evaluation of Hartmann and Braun Dissolved Oxygen Recorder
Determination of Dissolved Oxygen by Means of a Cambridge Analyzer

It is hoped that study and comparison of the information contained in this symposium will provide reliable guidance in selection of equipment and method for determination of dissolved oxygen whenever the latter is required.

Petroleum Products . . .

Symposium on Vapor Phase Oxidation of Gasoline STP 202†

Sponsored by Committee D-2 on Petroleum Products and Lubricants

It was the purpose of this symposium to review several valuable research projects in the field of the oxidation behavior of gasolines in automotive fuel induction systems. The gasoline-powered internal combustion engine is today by far the largest source of power in the world, and the successful operation of the gasoline engine is predicated on the rapid evaporation of the gasoline with air in the induction system, aided by heat at the manifold. This evaporation process must be carried out without having an appreciable residue on the inside walls of the induction system, and the four papers presented in the symposium describe research studies on various phases of this problem of induction system deposits.

This 72-page publication is now available. Price: $2.50; to members, $1.85. (A more detailed review of this book appears in the July issue of the ASTM BULLETIN.)

Symposium on Steam Turbine Oils STP 211†

Sponsored by Committee D-2 on Petroleum Products and Lubricants

In the introduction to this symposium it is brought out that the only reason for the existence of Technical Committee C on Turbine Oils and its various sections is to develop testing standards for evaluating turbine lubricating oils with the objective of giving better performance in turbine lubricating systems.

As is brought out in the first paper, the possibility of fires from oil leaks in turbine systems has greatly increased as a result of the use of higher temperatures in turbine operation. This has stimulated investigation of fire-resistant fluids for this application. There is a need for development of suitable test methods for evaluating these fluids, and the use of such fluids will involve new design and operational considerations. The ASTM may be able to contribute to the resolution of these matters. Another paper describes the Navy's continuing program of improving its turbine-gear lubricating oils to meet new machinery requirements resulting in the development of oils with improved performance under high gear tooth loads. The third paper reviews the mechanism of rusting occurring in the liquid and vapor regions of a turbine oil system. A new technique using radiotracer measurements and electron micrographs is described in another paper. The conclusion drawn in one of the papers is that the dynamic demulsibility apparatus is a very functional piece of equipment which permits the measuring of the demulsibility characteristics of steam-turbine oils under simulated operational conditions. Because of the design and operational characteristics of the dynamic demulsibility apparatus, sufficient oil is available (that has been in contact with water) for the determination of additive depletion as a result of water leaching and consequential effects upon performance characteristics. Another paper presents data on used turbine oils obtained from a turbine oil testing service covering the past ten years. In the last paper methods for the evaluation and performance of turbine oils are described.

The titles and authors of these papers are:

Organizational and Functional Aspects of Technical Committee C —Section I—C. F. Kottcamp
Laboratory Evaluation of Fire Resistant Turbine Fluids—G. H. S. Snyder, L. W. Manley, and N. V. Messina
Antiwear Requirements for Navy Turbine Oils—H. F. King and J. R. Belt
Rusting in Turbine Oil-Systems—N. W. Furby, F. J. Hanly, and J. A. Vincent
Monolayers of Anti-Rust Additives—H. E. Ries, H. D. Cook, and C. M. Loane
Water Leaching of Additives—E. W. Brennan and R. G. Moyer
Practices for Determining the Expected Life of Used Turbine Oils—R. G. Mastin
Evaluation and Performance of Turbine Oils—G. H. von Fuchs

This 110-page publication is now available. Price: $3; to members, $2.25.

Symposium on Composition of Petroleum Oils STP 224

Sponsored jointly by the American Petroleum Institute and ASTM Committee D-2 on Petroleum Products and Lubricants

It is the hope of the sponsoring groups that this symposium may serve as a starting point for a program of standardization

of methods for hydrocarbon type for petroleum fractions boiling above 600 F. The symposium contains 15 papers by authors who are acknowledged authorities in their fields. The authors represent nine American oil companies and one from Great Britain, a paper company which is a heavy consumer of petroleum products, and two members of the faculty of the Carnegie Institute of Technology.

The papers cover a wide range of research endeavor in the field of high molecular-weight oils from "New Thermal Diffusion Techniques Applicable to High Boiling Petroleum Fractions" to "Characterization of Hydrocarbons in Petroleum by Nuclear Magnetic Resonance Spectrometry."

The book is divided into three main chapters. The first chapter deals with Separations and covers volatility and adsorption, thermal diffusion, and solvent extraction. The second chapter is entitled Spectroscopic Methods and contains papers on infrared, mass spectrometry, and nuclear magnetic resonance. In the third chapter on General Methods and Correlations are papers covering the subjects of chemical treating, adsorption and physical property methods, analytical comparison, molecular weight determination, and correlative methods.

Symposium on Insulating Oils STP 218

Sponsored by Committee D-9 on Electrical Insulating Materials

Subcommittee IV on Liquid Insulation of ASTM Committee D-9 has held a series of seven symposia on insulating oils over a period extending from the fall of 1946 to the present. The first two symposia were published in ASTM BULLETINS No. 146, May, 1947, and No. 149, December, 1947. The others were printed as *Special Technical Publications 95, 135, 152, and 172*. The general theme of all these programs was derived from a very active interest of the subcommittee membership in the development of test methods and interpretation of test results for evaluating the serviceability of new and used insulating oils.

The first of the papers in the current program, by T. A. McConnell is essentially an evaluation of laboratory test results with service performance of oils in selected transformers on the Detroit Edison system. The laboratory tests were made in conjunction with an extensive cooperative survey started about 13 years ago with 19 laboratories engaged in the testing of oil samples from the transformers at about one-year intervals. The chief purpose of this survey was to determine the significance of sludge tests by ASTM Methods D 1313 and D 1314 in evaluating the resistance to oxidation of various types of new and used oils. It was the general practice of the 19 cooperating laboratories to make other selected tests commonly used as criteria of oil degradation. McConnell's paper goes far toward consummating the correlation of the data from all the laboratories with service performance.

The paper by E. L. Raab of the General Electric Co. is a detailed study of the data obtained on a cooperative sludge test program by 13 cooperating laboratories, using a modified ASTM Sludge Accumulation Test procedure with solid catalysts and the proposed revision of the IEC method using soluble catalysts. In general, it was the purpose of this study not only to correlate the results of two types of accelerated sludge tests but also to attempt to evaluate each of these tests with respect to service performance using the same oils in this study as were used in the Detroit Edison transformers. In an ideal sense, it has been the ultimate hope to develop a universal standard test method which would evaluate the relative service-life of an oil in its new state or at any stage of its degradation in service. The cooperative efforts of Mr. Raab and the General Electric Co. with the other laboratories helps greatly to resolve many questions regarding the limitations of the various sludge test methods.

This 43-page publication is now available. Price: $1.75; to members, $1.35.

Symposia on Railroad Materials and Lubricating Oils STP 214†

Symposium on Railroad Materials

The papers contained in this symposium deal with the use of residual type fuels in railroad diesel locomotive engines and other aspects of railroad operation. Since the cost of fuel represents a major portion of the operating expense of diesel engines, the utilization of less critical fuels in these engines without offsetting operational and maintenance problems is, of course, of vital interest to the railroads. The papers deal with research work conducted by railroads, petroleum companies, and engine builders on the use of residual type fuels in diesel engines, including experiments with a dual fuel system on locomotive diesel engines. Also included are papers relating to the standardization of railroad cleaning materials and methods and nondestructive testing practices on a large western railroad.

It is hoped that the papers contained in this publication will stimulate further research activity in the fields of locomotive fuels and lubricating oils as well as cleaning materials and methods of nondestructive testing on the part of the railroads and their suppliers. It is also hoped that these papers will serve, in some manner, to open new areas of mutual interest between the railroad industry and the ASTM so that the pooling of knowledge can result in benefit to all concerned.

The titles and authors of these papers are:

Operation of Railroad Diesel Locomotives with Dual Fuel Systems—P. V. Garin
Locomotive Lubricating Oil Requirements as Related to Fuels—J. L. Broughten and C. C. Moore
Performance of Residual Fuels in High Speed Diesel Engines—D. R. Jones, K. L. Kipp, and J. E. Goodrich
Laboratory Research on Burning No. 6 Residual Fuel in an 8¼ by 10 Opposed Piston Diesel Engine—R. H. Beadle
Railroad Cleaners and Cleaning Procedures—J. L. Ramsey
Standardization of Railroad Cleaning Materials and Methods—C. F. Jursch
Nondestructive Testing on Southern Pacific Railroad—A. S. Pedrick

Symposium on Lubricating Oils

Sponsored by Committee D-2 on Petroleum Products and Lubricants

This symposium presents the results of research studies on physical, chemical, and spectrographic analysis for determination of elements in lubricating oil. Two papers describe use of direct-reading spectrographic methods for (1) evaluation of used railroad oils, and (2) control of the manufacture of lubricating oil additives. In the latter it is shown that the speed of the instrument and method gave greater control at all stages of manufacture and resulted in the more effective use of plant equipment and laboratory manpower.

In the paper dealing with the application of the X-ray spectrograph to refinery control of additive metals in lubricating oils, the author shows that it is a quality-control tool in oil production. Another paper describes the factors involved in the setting up of a direct-excitation spectrographic method for the analysis of used lubricating oils. Sampling of lubricating oil from diesel locomotives is covered by one of the papers. Reference is also made to methods developed after a comprehensive study over the past five years of 15 spectrographic

methods of 23 laboratories. The last two papers describe the use of chromatography of diesel oils and the filtration of diesel engine lubricating oils.

Knocking Characteristics of Pure Hydrocarbons STP 225

Sponsored by API Project 45 and ASTM Committee D-2 on Petroleum Products and Lubricants

This publication makes generally available the data on the knocking characteristics of pure hydrocarbons that have been developed under the American Petroleum Project 45. While this information was developed primarily for the API Project, the usefulness of the data would be expanded by its broader distribution. To this end, the ASTM Committee D-2 was selected as the agency best suited for this distribution as it is largely composed of engine manufacturers, petroleum refiners, and consumers.

The objective of the project was to obtain samples of a wide variety of pure hydrocarbons and to relate their structures and physical characteristics with their respective knock limitations in engines. A variety of engine types and operation procedures were selected for this investigation because of the important effect of these variables on knock ratings of the hydrocarbons. The data were made available currently in annual reports distributed through the API. In preparing the present publication these data have all been checked against original sources to present them as free from error as possible.

ASTM Manual for Rating Aviation Fuels by Supercharge and Aviation Methods

This new Manual presents in a single cover the completely revised and up to date Supercharge Method D 909 and Aviation Method D 614, together with six supplements of recommended practices and procedures covering many useful details for the installation and mechanical care of the supercharge and aviation engines. The Appendices contain valuable supplementary information for conducting standard octane ratings of aviation fuel by both the Supercharge and Aviation Methods.

This 1957 Manual is a companion publication to the 1956 Manual which provides similar information for the Motor and Research Methods.

There is in course of preparation by the Division on Combustion Characteristics of Committee D-2, a third Manual which will include the Cetane Method (D 613) for Determining the Ignition Quality of Diesel Fuels. This third Manual will also include six separate Appendices containing similar information for making cetane ratings of diesel fuels. It is expected that the Cetane Manual will be available sometime late in 1958.

1957 Supplement to ASTM Manuals of Engine Test Methods for Rating Fuels

This Supplement presents in detail the changes that should be made in the 1956 ASTM Manual for Rating Motor Fuels by Motor and Research Methods. Included are the completely revised Motor Method (D 357 – 56) and the Research Method (D 908 – 56).

One of the principal changes in the Motor and Research Methods is the provision for carburetor cooling when there is a tendency for the sample to bubble or boil in the fuel-level sight glass in making the adjustment of fuel-air ratio.

Included also are changes necessary in the Appendices of the 1956 Manual to provide for carburetor cooling of the motor and research engines.

The Supplement also presents changes in the 1952 Manual of Engine Test Methods. Included is the completely revised and up to date Aviation Method (D 614 – 56 T) and also the Cetane Method for Diesel Fuels (D 613 – 56 T). Included with the latter method are changes in the 1952 Manual and also its 1953 Supplement to provide for use of the ignition delay meter in determining cetane number by Method D 613.

Included is a new Supplement on Instrumentation which describes in complete detail the ignition delay meter, its calibration, operation, and use in determining cetane number.

Chemical Analysis . . .

Symposium on Ion-Exchange and Chromatography in Analytical Chemistry STP 195

Sponsored by Committee E-3 on Chemical Analysis of Metals

This 1956 symposium is the first in an annual series of symposia sponsored by Committee E-3 on timely subjects of importance to ASTM members concerned with analysis of materials. They are planned to acquaint ASTM members with new methods, techniques, etc., which are actually or potentially capable of use in standard methods of analysis. This first symposium is intended to present a picture of the materials available, or under development, for ion-exchange and chromatography, the basic theory of their use, and examples of their application for separation and analysis of materials. Primary emphasis is on metals, but data of value to people concerned with other materials are included. Three of the papers present a coverage of ion-exchange and associated chromatographic techniques applicable to chemical analysis in general. The fourth paper covers the application of ion-exchange techniques specifically to the analysis of metals.

Symposium on Spectrochemical Analysis for Trace Elements STP 221*

Sponsored by Committee E-2 on Emission Spectroscopy

It is part of the duties of Committee E-2 to keep informed regarding the latest advances in emission spectrochemical analysis. To this end from time to time symposia on one of the many aspects of emission spectroscopy are arranged at which speakers present the latest developments in a particular area.

In recent years it has become more and more apparent that important scientific advances have been attained because analytical methods have been developed for estimating very low concentrations of certain elements. Today whole industries are greatly influenced because of the ability to determine or control trace amounts of elements present in materials. These newly perfected techniques have found application in such diverse fields as medicine, animal nutrition, metallurgy, plant nutrition, and geological exploration. Research in the semiconductor and transistor fields has shown the great importance of knowledge of the presence and concentration of elements at increasingly lower levels in supposedly pure materials. In a similar manner atomic energy research has placed greater and greater demands upon the analyst to provide data concerning elements at concentration levels which a few years ago defied determination.

Because of this growing interest in trace analysis and because emission spectroscopy is one of the few methods available for analytical work at trace levels, this symposium was arranged. By bringing together a group of authors from widely differing

fields of scientific endeavor who have worked on the problem of spectrochemical analysis for traces, it is hoped that this symposium will serve to transfuse new techniques and ideas.

Index to the Literature on Spectrochemical Analysis, Part IV (1951–1955) STP 41D

This is the fourth part of a series of bibliographical surveys of the literature of spectrochemical analysis. The first part (second edition) was published in 1941 and covered the literature for the years 1920 through 1939 with 1467 references. The second part, published in 1947, included about 1044 references with detailed abstracts to articles appearing in 1940 through 1945. Part III contains 1264 references and covers the years 1946 through 1950. It is expected that Part IV will also contain over 1000 references and will bring the bibliographical survey of the literature of spectrochemical analysis up to date through the year 1955.

Soils . . .

Symposium on Vane Shear Testing of Soil STP 193

Sponsored by Committee D-18 on Soils for Engineering Purposes

The purpose of this symposium is to acquaint the profession with a relatively new tool for obtaining the in-place shear strength of medium to soft clay soils and organic silts. The Scandinavian countries have pioneered the development of the vane test and now use it widely in virtually all exploratory work where shear strengths are needed. There has been no attempt to standardize the test, although, as this symposium will show, much has already been accepted as standard. An additional purpose of the symposium is to bring in focus the developments to date, so that the possibility of standardization can be considered. If it is possible to standardize certain elements of the vane test without stifling or restricting further progress through research and experimentation, then it would be desirable to do so.

The titles and authors of these papers are:

Introduction—*J. O. Osterberg*
An Apparatus and Method of Vane Shear Testing of Soils—*Harold J. Gibbs*
Deep Vane Tests in Gulf of Mexico—*Carl W. Fenske*
Vane In-Place Soil Shear Measuring Device—*W. A. Hill*
The Use of a Field Vane Apparatus in Sensitive Clay—*W. J. Eden and J. J. Hamilton*

Additional discussion of this symposium was solicited from Scandinavian scientists and is included as part of this symposium.

Papers on Soils STP 206†

Sponsored by Committee D-18 on Soils for Engineering Purposes

A wide range of subjects covering the many aspects of soils investigation and testing is presented in this publication devoted to this important field of research and testing. Soils testing machines, electrical resistivity surveys, soil-cement mixtures, consolidation of pipe bedding, deadman anchorage tests, and many other varied topics are discussed in the twelve papers included in this publication.

Titles and authors of these papers are:

Soil Explorations for Site Selection and Engineering Design—*K. B. Woods*
A Generalized Theory of Soil Resistance—*W. S. Housel*
A Procedure for Separately Evaluating Friction and Cohesion by a Consolidated Direct Shear Test—*L. A. Palmer, P. B. Brown, and C. M. Yeomans*
Experiences with the Consolidation of Pipe Bedding by Vibration on the San Diego Aqueduct—*W. G. Holtz*
The Use of Vibratory Compactors on Granular Base Courses—*C. R. White*
Compaction of Cohesive Soil by Low Frequency Vibration—*F. J. Converse*
Microseismics—*R. K. Bernhard*
Experiences with Electrical Resistivity Surveys on Foundation and Subsurface Investigations in Southern California—*R. A. Maurseth, J. B. Howe, and S. N. Mitchell*
Tests of Concrete Deadman Anchorages in Sand—*J. E. Smith*
Field Tests on Laterally Loaded Instrumented Piles—"Fixed Head" Loadings in Sand—Free Head Loadings in Clay—*H. G. Mason*
Strength and Elastic Properties of Soil-Cement Mixtures—*E. J. Felt and M. S. Abrams*
Universal Soil Testing Machine—*J. W. Maloney*

Structures . . .

Symposia on Design and Tests of Building Structures—Seismic and Shock Loading—Glued Laminated and Other Constructions STP 209†

Sponsored jointly by Committees D-7 on Wood and E-6 on Methods of Testing Building Constructions

This publication consists of two symposia, both of which are of equal value and interest to those in the building construction field. The continued recurrence of earthquakes in the West Coast Area have shown they need not result in the destruction of a building if proper design is used. The papers on this subject present valuable information on tests and design. Glued-laminated structural members are being increasingly utilized for building construction with the advancement in quality of wood adhesives. The papers in this field discuss factors affecting strength and design principles.

This 91-page publication is now available. Price: $2.75; to members, $2. (A more detailed review of this book appears in the September issue of the ASTM BULLETIN.)

Symposium on Full-Scale Tests on House Structures STP 210†

Sponsored jointly by Committees D-7 on Wood and E-6 on Methods of Testing Building Constructions

The five papers comprising this symposium probably constitute the first published collection of papers descriptive of such full-scale structural tests of completed house structures. Study of the papers will show both advantages and disadvantages of this type of full-scale testing and will suggest further lines calling clearly for intensified research, directed toward further economy in the structural design of such buildings.

This 64-page publication is now available. Price: $2.50; to members, $1.85. (A more detailed review of this book appears in the July issue of the ASTM BULLETIN.)

Symposium on Wood for Marine Use and Its Protection from Marine Organisms STP 200†

Sponsored by Committee D-7 on Wood

The papers are intended to present a picture of marine borer problems and the difficulties encountered, the results of some special research studies on the nature and distribution of certain organisms, the most susceptible zone of attack, and the effectiveness of certain specific protection procedures. It is hoped that the information presented will serve as stimulus and encouragement to the further research that is the key to improved service.

This 56-page publication is now available. Price $2; to members, $1.50. (A more detailed review of this book appears in the May issue of the ASTM BULLETIN.)

Symposium on Thermal Conductivity Measurements and Applications of Thermal Insulation STP 217

Sponsored by Committee C-16 on Thermal Insulating Materials

The process by which research establishes property values and limits for products, and, in turn, methods of test which are broadly applied and subsequently revised as experience dictates, is well illustrated in this symposium. Two papers present analyses and experimental procedures by which these criteria can be developed; two others deal with improvements and modifications of the apparatus within the scope of the method and its extension to uses at lower temperatures; and the phase of property values research is exemplified by two papers dealing with moisture in relation to thermal insulation.

This 92-page publication is now available. Price: $2.75; to members, $2. (A more detailed review of this book appears in the September issue of the ASTM BULLETIN.)

Bibliographical Abstracts of Methods for Analysis of Synthetic Detergents STP 150 B

Sponsored by Committee D-12 on Soaps and Other Detergents—Prepared by Jay C. Harris

The first publication on Bibliographical Abstracts of Methods for Analysis of Synthetic Detergents appeared in 1953 as *STP 150* and was replaced in 1956 by *STP 150 A*. The continued effort to standardize methods for surface-active agent analysis has necessitated continuous scrutiny of the literature. Ordinarily a compilation of this kind might be issued at less frequent intervals, but to be of greatest assistance to those working in this field, the abstracts should follow the original literature as closely as possible. Hence, though the number of references may be fewer, their availability should outweigh the inconvenience of more frequent preparation.

Thorough indexing with the analyst's needs in mind has been continued. Methods have been classified as to type, as have the surface-active agents. References have been numbered and lettered to maintain the proper author sequence. The seven abstracts for 1956 in *Special Technical Publication 150 A* have been renumbered and included to simplify their ready identification. Users of these abstracts are urged to supply corrections or additions so that these abstracts may become complete.

Papers on Cement and Concrete STP 205†

Sponsored jointly by Committees C-1 on Cement and C-9 on Concrete and Concrete Aggregates

Cement and concrete, being major construction materials, received their share of attention in the program of technical papers presented during the Second Pacific Area National Meeting. This book contains the papers presented at the Session on Cement and at the Session on Concrete

The papers presented at the concrete session deal with data on the rating of performance of various types of portland cement with different quantities of various types of replacement materials; tests of prestressed expanded shale concrete beams under short-time and sustained loads; abrasion tests to evaluate the effect of aggregate quality on the resistance of concrete to abrasion; and the "point count method" of determining the cement content of hardened portland-cement concrete by analysis of a cut section with a traveling microscope.

The papers presented at the cement session deal with the effect of storage on the air-entraining properties of portland cement; hydrophobic cement; carbonation of hydrated portland cement; and alkali aggregate phase of chemical reactivity in concrete.

Papers on Road and Paving Materials STP 212†

Sponsored by Committee D-4 on Road and Paving Materials

The five papers comprising this symposium represent a wide range of subject material and give interesting information and data on aggregate and bituminous materials used for paving purposes. Four of the five papers discuss testing techniques and correlation and reproducibility of laboratory tests involving the evaluation of properties and characteristics of paving asphalts. The fifth paper presents a very thorough review of studies on the effect of shape, size, and surface roughness of aggregate particles on the strength of granular materials used in bituminous mixtures.

Titles and authors of these papers are:

The Operation, Control and Application of the Infrared Weathering Machine—California Design—*John B. Skog*

Correlation Between Laboratories on Results of ASTM Tests for Asphalts—*Ernest Zube and John B. Skog*

Sliding Plate Microviscometer for Rapid Measurement of Asphalt Viscosity in Absolute Units—*R. L. Griffin, T. K. Miles, C. J. Penther, and W. C. Simpson*

Reproducibility in Oven Heat Tests for Paving Asphalts—*R. S. Winniford*

Effect of Shape, Size, and Surface Roughness of Aggregate Particles on the Strength of Granular Materials—*B. A. Vallerga, H. B. Seed, C. L. Monismith, and R. S. Copper*

This 82-page book is now available. Price: $2.75; to members, $2.

HEADQUARTERS HOTELS . . .

. . . good places to stay when attending National Meetings —why make it difficult to get in?

While the above suggestion may sound a little off beat it is not so ridiculous as it seems. Many committees start their meetings at our Committee Week (February) or the Annual Meeting (June) on Wednesday morning. With the replacement of pullman travel by airplane, this means that many of our members arrive at these meetings on Tuesday night. Our Headquarters Hotels are *always filled* on Monday and Tuesday nights when meetings are running Monday, Tuesday, and Wednesday. Those members arriving Tuesday night must, therefore, be sent to cooperating hotels—yet, on Wednesday night rooms become available at the headquarters hotel because of the departure of guests whose meetings ended Wednesday afternoon.

Please help us to help you. Start your Wednesday meetings late enough so that you can plan to arrive at the hotel on Wednesday morning. But even more important, never allow an unused reservation to go uncancelled.

Actions on Standards

The Administrative Committee on Standards is empowered to pass on proposed new tentatives and revisions of existing tentatives and standards offered between Annual Meetings of the Society. On the dates indicated below, the Standards Committee took these actions.

STEEL

Tentative Methods for Ultrasonic Testing and Inspection of Turbine and Generator Steel Rotor Forgings (A 418 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—This method, utilizing high-frequency sound waves, is intended to apply to turbine and generator steel rotor forgings covered in the Specifications for Carbon and Alloy Steel Forgings for Turbine-Generator Rotors and Shafts (A 292) and for Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts (A 293). It shall supersede the Recommended Practice for Ultrasonic Testing and Inspection of Heavy Steel Forgings (A 388) when turbine and generator steel rotor forgings are to be inspected.

Development of the method grew out of discussions within Committee A-1's Task Group on Brittle Fracture which are intended to correct manufacturing practices or inspection procedures which may have been responsible for the series of failures in power stations several years ago.

Tentative Specification for Uncoated Seven-Wire Stress-Relieved Strand for Prestressed Concrete (A 416 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—The great increase in use of prestressed concrete in construction has created a widely felt need for an ASTM specification covering the steel cable used to prestress the concrete.

Tentative Specification for Upholstery Spring Wire for Zig-Zag Type and Square Formed Type and No-Sag Type Spring Units (A 417 – 57 T)(Approved Sept. 13, 1957)

New Tentative.—This, the second specification produced by Subcommittee III of Committee A-1 which was organized in 1956 to meet the demand for ASTM specifications for cold-drawn spring wire, covers types for automobile seats and backs and for furniture spring units. It is not intended for the manufacture of mechanical springs.

Tentative Specification for Hot-Rolled Carbon-Steel Sheets, Commericial Quality (A 414 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—This specification represents an extension of the requirements formerly in Specification A 245 (see immediately below) which has been split.

Tentative Specification for Heavy Gage Structural Quality Flat Hot-Rolled Carbon Steel Sheets (A 245 – 52 T) (Approved Sept. 13, 1957)

Revision.—This specification has been split to permit the separate promulgation of the requirements now covered in the new Tentative A 414 (see immediately above). The light gage structural grade of sheet formerly covered by Specification A 246 has now been added to Specification A 245.

Tentative Specification for Carbon-Steel Castings Suitable for Fusion Welding for High-Temperature Service (A 216 – 65 T) (Approved Sept. 13, 1957)

Tentative Specification for Ferritic and Austenitic Steel Castings for High-Temperature Service (A 351 – 52 T) (Approved Sept. 13, 1957)

Tentative Specification for Ferritic Steel Castings for Pressure Containing Parts Suitable for Low-Temperature Service (A 352 – 55 T) (Approved Sept. 13, 1957).

Tentative Specification for Alloy-Steel Castings Specially Heat Treated for Pressure Containing Parts Suitable for High-Temperature Service (A 389 – 56 T) (Approved Sept. 13, 1957)

Standard Specification for Alloy-Steel Castings for Pressure Containing Parts Suitable for High-Temperature Service (A 217 – 55) (Approved Sept. 13, 1957)

Revision.—The reference in these specifications to Magnetic Particle Testing Methods (A 272) has been replaced by a reference to the more definitive magnetic particle testing method (E 109). Also added is reference to the new Reference Photographs of Magnetic Particle Indications (E 125 – 56 T). Specification A 217 is reverted to tentative status.

Tentative Specification for Carbon Steel Axles for Cars and Tenders (A 21 – 57 T) (Approved Sept. 13, 1957)

Revision.—Permissible variations for check analysis are added and the difference in requirements for the drop test of axles 65 in. and under in length are eliminated. Requirements for marking are also revised.

Tentative Specification for Alloy Steel Bolting Material for High-Temperature Service (A 193 – 56 T) (Approved Sept. 13, 1957)

Revision.—Type 416 steel (selenium added) is now included in these specifications. The term "cold drawn" when applied to the austenitic steels is felt to be ambiguous and misleading and is changed to read "strain hardened."

Tentative Specifications for Alloy Steel Bolting Materials for Low Temperature Service (A 320 – 56 T) (Approved Sept. 13, 1957)

Revision.—In Section 15 (a) the words "or with British Whitworth threads when specified" are deleted but this deletion will not prevent the purchaser's ordering Whitworth threads or any other kind. The term "cold-drawn" when applied to austenitic steels is changed to "strain hardened."

Tentative Specification for Steel Forgings for Turbine Rotors and Shafts (A 293 – 55 T) (Approved Sept. 13, 1957)

Revision.—In Table I "Chemical Requirements," changes are made in minimum vanadium content for class 7 and in Section 11 and Table III mechanical property requirements are changed for classes 6 and 7. These are the result of recommendations by some of the major producers.

Standard Specification for Forged or Rolled Carbon and Alloy Steel Flanges, Forged Fittings, and Valves and Parts for Low-Temperature Service (A 350 – 57) (Approved Sept. 13, 1957)

Tentative Specification for Seamless and Welded Steel Pipe for Low-Temperature Service (A 333 – 55 T) (Approved Sept. 13, 1957)

Revision.—Impact test requirements are clarified and a new grade 4 is added. Specification A 350 is reverted to tentative.

Tentative Specification for Alloy Steel Seamless Drum Forgings (A 336 – 57 T) (Approved Sept. 13, 1957)

Revision.—The ASME Boiler and Pressure Vessel Committee has recommended revision to permit ordering of forgings of steel grades listed in Specifications for Seamless Alloy Steel Pipe (A 335) under these specifications. The chemical, tensile, heat treatment, and marking requirements of A 335 shall apply except the forgings shall conform to the chemical requirements of A 335 only with respect to ladle analysis. On check analysis they may deviate from these limits to the extent permitted in A 336.

Tentative Specification for Cold-Rolled Carbon Steel Deep-Drawing Sheets, Special Killed for Miscellaneous Drawn or Severely Formed Parts (A 365 – 53 T) (Approved Sept. 13, 1957)

Tentative Specification for Cold-Rolled Carbon Steel Sheets, Commerical Quality (A 366 – 53 T) (Approved Sept. 13, 1957)

Revision.—Basic changes with respect to product sizes and tolerances that have taken place in the sheet steel industry are reflected in the revisions in these two specifications.

Standard Specification for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A 120 – 54) (Approved Sept. 13, 1957)

Revision and Reversion to Tentative.—The new steel making process using an

oxygen lance (known as the LD process in Europe) has become established in this country. Several producers have asked that steel made by this process be included with the present open hearth and basic bessemer processes in these steel pipe specifications. The term "basic oxygen process" has been decided upon to cover the LD and related processes.

Standard Specification for Carbon and Alloy-Steel Forgings for Magnetic Retaining Rings for Turbine Generators (A 288 – 55) (Approved Sept. 13, 1957)

Standard Specification for Carbon and Alloy Steel Forgings for Turbine Generator Rotors and Shafts (A 292 – 55) (Approved Sept. 13, 1957)

Standard Specification for Carbon and Alloy Steel Forgings for Turbine Generator Rotors and Shafts (A 294 – 55) (Approved Sept. 13, 1957)

Tentative Specification for Carbon and Alloy Steel Forgings for Turbine Rotors and Shafts (A 293 – 55 T) (Approved Sept. 13, 1957)

Revision.—As a result of the general trend of industry to specify lower phosphorus and sulfur in high-strength rotating parts, the maximum permissible amounts of these elements is reduced from the present 0.50 to read 0.40 per cent in this group of specifications. A 288, A 292, and A 294 revert to tentative status.

Standard Specifications for Carbon Steel Forgings for Railway Use (A 236 – 57) (Approved Sept. 13, 1957)

Revision and Reversion to Tentative.—These changes are a result of the intention of industry toc orrelate American Assn. of Railroads and ASTM specifications.

Tentative Specification for Carbon Steel Chain (A 413 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—The Standard Specification for Iron and Steel Chain was rewritten in 1956 to cover only wrought iron chain and this new specification now covers the steel chain formerly purchased under the old Specification A 56.

Tentative Specification for Carbon Steel Sheets of Flange and Firebox Qualities (A 414 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—Requested by the ASME Boiler and Pressure Vessel Committee, this specification covers three grades of flange and three grades of firebox steels.

WROUGHT IRON

Tentative Specification for Electric-Fusion (Arc) Welded Wrought Iron Plate Pipe (A 419 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—For some time Committee A-2 has been aware of the need for an ASTM specification covering this material which is produced by a number of fabricators. Wrought iron pipe was and is being produced under the applicable portions of Specifications for Electric-Fusion (Arc) Welded Steel Plate Pipe (A 134) which, however, contains no information on the differing material characteristics of wrought iron.

ELECTRICAL RESISTANCE AND CONTACT MATERIALS

Tentative Recommended Practice for Dimensional Standards for Projection Welding Contacts (B 321 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—This practice, of benefit to manufacturers and users in limiting the number of dimensional combinations of this type of contact, could reduce prices, provide a better stock reserve, and result in better delivery on orders. It will also aid designers in selection of contact dimensions.

CLAY PIPE

Tentative Specification for Extra Strength Clay Pipe (C 200 – 55 T) (Approved Sept. 13, 1957)

Revision.—Engineers have objected to the provision which permitted the pipe supplier to gain acceptance of his product when less than 20 per cent of the shipment failed to meet the test requirements. This provision is eliminated; and full internal diameter pipe is provided for.

Tentative Specification for Extra Strength Ceramic Glazed Clay Pipe (C 278 – 55 T) (Approved Sept. 13, 1957)

Revision.—Provisions for ceramic glaze class I and unglazed pipe class II are added, as well as provisions for full internal diameter pipe.

Standard Specifications for Standard Strength Ceramic Glazed Clay Sewer Pipe (C 261 – 54 T) (Approved Sept. 13, 1957)

Revision and Reversion to Tentative.—Provisions for ceramic glazed class I and unglazed pipe class II are added. Eliminated is the provision which permitted the pipe supplier to gain acceptance of his product when less than 20 per cent of the shipment failed to meet the test requirements.

Standard Specification for Standard Strength Clay Sewer Pipe (C 13 – 54) (Approved Sept. 13, 1957)

Standard Specifications for Standard Strength Perforated Clay Pipe (C 211 – 50) (Approved Sept. 13, 1957)

Revision and Reversion to Tentative.—The provisions which permitted the manufacturer to have his pipe accepted when less than 20 per cent of a shipment failed to meet test requirements, have been changed in both specifications to eliminate acceptance of a shipment, part of which may have failed to meet the tests.

GYPSUM

Specifications for Gypsum Plasters (C 28 – 55) (Approved Aug. 26, 1957)

Tentative Revision.—Committee C-11 has found that there is no need to exclude strength requirements for ready-mixed plasters for use over porous masonry bases. The tentative revision accordingly provides for the deletion of this exception.

PETROLEUM PRODUCTS AND LUBRICANTS

Tentative Specifications for Gasoline (D 439 – 56 T) (Approved Aug. 26, 1957)

Revision.—Current values of octane numbers of regular and medium-price gasolines are reviewed annually by Committee D-2's Technical Committee A on Gasoline. The 1956–57 winter survey resulted in a change in Research Method Octane Numbers for Type A and Type B gasolines from "83 or 92" to "84 or 93."

INDUSTRIAL WATER

Tentative Method of Test for Oxidation-Reduction Potential of Industrial Water (D 1498 – 57 T) (Approved Sept. 13, 1957)

New Tentative.—This method, requested by industry, is particularly valuable where oxidation or reduction are pertinent properties, as in chlorinated waters. It does not deal with the manner in which the solutions are prepared, the theoretical interpretation of the oxidation-reduction potential, or the establishment of a standard oxidation-reduction potential for any given system. It is applicable to all types of industrial water at temperatures below 38 C.

Tentative Method of Test for Iron in High-Purity Water (D 1497 – 57 T)

Revision.—This method is revised to provide for the optimum pH of the test solution, and changes have been made in the reagents and test procedure to improve the precision of the method.

CHEMICAL ANALYSIS OF METALS

Tentative Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron (E 30 – 56 T) (Approved Aug. 26, 1957)

Revision.—Committee E-3, in response to an expressed need, has added a procedure for determination of cobalt in stainless steel by the photometric nitroso-R-salt method.

All Items on Standards Ballot Approved

THE canvass of the results of the 1957 letter ballot shows that the membership of the Society has approved all items listed on the ballot. These include the adoption of revisions of 96 existing standards, and adoption as standard of 63 tentatives. These actions will all be reflected in the 1957 Supplements to the 1955 Book of Standards now in preparation.

ACR Notes

Administrative Committee on Research

With Hand and Mind

By WALTER J. SMITH[1]

IN THE accomplishment of research assignments, there is a proper balance of effort between the library and desk on the one hand and the laboratory on the other. However, the ultimate findings or advances are usually and finally the product of the laboratory. Here the accumulation of knowledge, understanding, and experience of the past must be brought to bear in the experiment which is expected to yield new information or demonstrate a theory. The great importance of laboratory work is seldom denied, but there is an attitude, shared by many in the technical and scientific professions, that manual skill is not particularly important in research and that intellectual ability alone is sufficient to design and consummate a costly experiment. This attitude could easily lead to impairment of an entire research project. Many of us know otherwise—that the manual skill of the researcher can be enormously useful and, on occasion, so important that it can determine the difference between success or failure.

We seem to have inherited from ancient civilizations some notion that anything akin to manual labor is undignified for the intellectual man. Undoubtedly, this attitude was propagated in the universities during the ages when only academic subjects were taught. Historically, the learned professions have been the clergy, law, and medicine. With the possible exception of medicine, learning had no use for any associated manual skills. It is understandable then why a sharp distinction was drawn between those who lived by their knowledge and those who labored by hand. Perhaps it was only human for the educated to feel superior and to pass this along in their writings!

However, it is not so understandable, in this technological era, why so many homes and schools still foster the idea (merely by implication perhaps, but nonetheless effectively) that the homely arts and manual skills are only for those who intend to enter the trades. If they could only appreciate how much these skills acquired in youth can enhance and enrich any man's activities throughout a lifetime.

Fortunate indeed is the research group staffed with those having both the understanding and competence to devise, improvise, and create the many special aids and appliances that keep a work program moving smoothly ahead. If a glass tube snaps, it is promptly mended; if a wire connection breaks, it is quickly resoldered; and if a meter misbehaves it is soon corrected. This is what one should expect. Yet there are laboratories (and of good repute) in which even a small accident can mean hours or days of lost time.

There are those who argue that good technicians, available at moderate cost, can do all necessary mechanical work and make accurate observations. This is often accepted practice and usually sufficient for routine work. For excursion into the new experimental area, however, there is no substitute for the complete professional man.

Of course, we know that many brilliant and creative people never learn to work with tools. Often there is neither aptitude nor desire to gain facility in handicrafts. Such people must depend upon others, and they form a group outside our immediate consideration.

We believe there is much to be gained by encouraging all young people to develop not only intellectual but also manual skills. If this is done, those who finally enter the creative professions will profit by their added powers of accomplishment. Moreover, they will be among those fortunate people who, in the knowledge of their strength, can face life with greater confidence.

[1] Chemical engineer, Arthur D. Little, Inc.

Plastics Group Tackles Radiation Problems

The standardization of exposure methods for determining effects of nuclear and high-energy radiation on plastics and electrical insulation is the problem assigned to the group pictured here, which met at the Naval Air Material Center in Philadelphia on September 13. Progress toward developing standard procedures was reported and it is expected that following another meeting late in October the group will have a draft ready to present to Joint Subcommittee II on Radiation Effects of ASTM Committees D-9 on Electrical Insulating Materials and D-20 on Plastics, when they meet in November at Virginia Beach. Standing, left to right are Seymour Dondes, Rensselaer Polytechnic Institute; Robert McFedries, Dow Chemical Co.; M. Oulten, Army Signal Supply Agency; Charles A. Cassola, Naval Air Material Center; William W. Parkinson, Oak Ridge National Laboratory; and Donald Metz, Brookhaven National Laboratory. Seated, left to right, are George E. Rugger, Picatinny Arsenal; Oscar Sisman (Chairman), Oak Ridge National Laboratory; J. Hartley Bowen, Jr., and Eleanor Th. Vadala, Naval Air Material Center; and John F. Kirchner, Battelle Memorial Institute.

Also meeting on the same day, but not shown, is the Task Group on Gamma Dosimetry under the chairmanship of J. Hartley Bowen Jr. Of a large number of possible methods for measuring gamma ray dosage Mr. Bowen's group has selected two for standardization. One method depends on gamma-photon oxidation of ferrous sulphate and the other on the decomposition of nitrous oxide.

Society of Rheology 1957 Annual Meeting

THE SOCIETY of Rheology will hold its 1957 Annual Meeting in Princeton, N. J., November 7–9. The technical sessions will be held at the Textile Research Institute.

An important feature of the meeting will be the award of the Society's Bingham Medal on the evening of Nov. 7 to Clarence M. Zener in recognition of his important work in the viscoelastic behavior of metals.

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RACE STREET
PHILADELPHIA 3, PENNA.

New Committee on Flexible Barrier Materials

Pose Problems on Composite Material Standards

PLASTIC FILMS, metal foils, coated papers, and various combinations of these materials are included in a group known as flexible barriers. These materials are used to prevent the passage of moisture, gases, odors, and other elements from one location to another. Possibly the most common usage of flexible barrier materials is in packaging. An example of the use of flexible barrier materials, other than for packaging, is a polyethylene membrane used as a vapor barrier in concrete slab-on-ground construction.

Following considerable preliminary investigation by the ASTM Staff, a conference was held on May 28 of this year attended by a very sizable and representative group of those interested in this field. The conference resulted in a wholehearted endorsement for work to be started in ASTM toward the development of standards. A Steering Committee was established at the time of the conference to draft a proposed scope and organization of a new ASTM technical committee. On September 17 the Board of Directors authorized the formation of a new technical committee, appointing J. M. Cowan, the National Flexible Packaging Assn., as temporary chairman.

The flexible barrier materials field has been classified into three categories, as follows:

1. *Basic Materials.*—This type of material is tentatively defined as flexible homogeneous barrier material. Included in this type would be such materials as metals, plastics, paper, bituminous, porcelain, coal-tar derivatives, and cellulosic materials (including cellophane).

2. *Combined or Composite Materials.*—This type of material is defined as flexible barriers composed of two or more basic materials in the form of laminated, coated or impregnated structures. It is felt that of the three types of materials the composite materials will require the most attention with respect to the development of standards.

3. *Barrier Applications.*—This type of material is tentatively defined as flexible barrier materials in final form. Several applications include industrial, agricultural, electrical, and packaging applications.

The proposed scope of the new committee is as follows:

The development of definitions of terms, methods of tests and specifications for flexible barriers, including basic and composite materials and their applications, and the promotion of research in this field. Standards covered by other committees shall be used when applicable.

Plans are being made for the prompt organization of the new committee which will probably be in the "F" group of ASTM technical committees, being in the use category. The Steering Committee will be interested in developing a balanced membership which will be as completely representative as possible of the industry, both in consumer and producer members. Any individual or organization which may have an interest in this new activity is encouraged to contact ASTM Headquarters.

Prepare Now for ASTM Photographic Exhibit

THE Photographic Exhibit has been one of the outstanding features of ASTM Annual Meetings. It is held every other year in conjunction with the Exhibit of Testing and Scientific Apparatus and Laboratory Supplies. E. F. Walsh, Chairman of the Exhibit which will be held at the Annual Meeting in Boston, June 22–28, urges everyone making use of photography in connection with their technical and professional work to submit one or more entries. Students particularly are urged to submit entries relating to their work in photomicrography and electron micrography. Additional applications may be obtained from Society Headquarters.

Members of the committee are Chairman E. F. Walsh, The Narragansett Electric Co.; R. W. Chadbourn; G. W. Cook, Collyer Insulated Wire Co.; W. G. Dahlstrom, U. S. Steel Corp.; Mary R. Norton, Watertown Arsenal; S. R. O'Dette, Alsop Engineering Corp.; H. A. Pratt, University of Maine; and G. W. Trumbour, Polaroid Corp.

DISTRICT ACTIVITIES

Atomic Power Plant Described at New York

The New York District opened the 1957–58 season with a meeting on the peaceful use of the atom. On September 26 an audience of over 220 heard G. R. Milne, mechanical engineer of Consolidated Edison Co., describe the company's Indian Point Nuclear Power Plant. Past President L. C. Beard, described it as "one of the most objective and factual discussions of nuclear power plant engineering design problems and costs that I have ever heard." The meeting's co-sponsor was the New York Section, Power and Industrial Group of AIEE.

Mr. Milne discussed in some detail the design factors of the plant now under construction at Buchanan, N. Y. He paid particular attention to the materials that are being used in the construction of the plant and which are necessary to handle the atomic fuel elements. He also covered the handling of superheated steam and its use to produce electricity. The first generating unit will be capable of producing 275,000 kw when the plant goes into operation.

Radiography Featured at St. Louis

The St. Louis District, meeting jointly with the American Welding Society and the Engineers' Club of St. Louis, on Thursday, October 10, heard a "Discussion and Demonstration in the Use of Radiography as Applied to Weldments," by C. D. Trowbridge, director of the St. Louis Testing Laboratories, and K. M. Boekamp, technical director of the Radiographic Department of that company. They demonstrated the interpretation of existing code films and discussed safety practices as well as techniques employed in various types of radiography.

Cellulose

Cellulose Standard Samples Available to World

COMMITTEE D-23, at its September meeting in New York City, announced a significant milestone in the history of cellulose analysis. Eight carefully prepared purified celluloses representing substantially the entire range of commercial production are now available. They will be useful to laboratories throughout the world that are interested in the various American committees concerned with standardization of cellulose methods of analysis.

The eight samples were prepared and stored with the cooperation of the suppliers by Karen Wilson, chairman of the International Committee on Cellulose Analyses, and E. E. Hembree, chairman of the subcommittees on Alkali Solubility Tests of both ASTM Committee D-23 and ICCA.

Standard samples are available for:

1. Cotton linters, acetate grade (Buckeye Type 1AR500)
2. Acetate grade sulfite pulp (Rayonier's Rayaceta)
3. Prehydrolyzed sulfate tire cord pulp (Buckeye Type V-5)
4. Rayon grade sulfite (Riordan's Novocell)
5. Cellophane grade sulfite (Rayonier's Rayamo)
6. Paper pulp, regular grade (Swedish pulp)
7. Paper pulp, greaseproof grade (Swedish pulp)
8. Greaseproof grade sulfite (Swedish pulp)

These standard samples will permit studies of new methods or new approaches to old methods using identical samples of cellulose. The resulting fund of comparable data will become increasingly valuable and permit statistical evaluation.

Inquiries concerning aliquots of these samples should be addressed to E. E. Hembree, Buckeye Cellulose Corp., 2899 Jackson Ave., Memphis 1, Tenn. European inquiries should be addressed to Miss Karen Wilson, chairman, International Committee on Cellulose Analysis, Uddeholm Aktiebolag Skoghallsverken, Skoghall, Sweden.

The committee also reported on new techniques of paper partition chromatography for the isolation and identification of the sugars in cellulosic materials. A brochure of all chromatographic methods has been circulated to committee members for study.

Samples are being sent out for interlaboratory collaborative testing of the Karl Fischer method for moisture determination. Some difficulty has been experienced with certain extraction solvents.

A method for the preparation of cellulose samples prior to degree of polymerization determinations is being submitted to subcommittee letter ballot. The precleaning of cellulose samples prior to fractionation is essential for reliable polymolecularity data. Much of the present published data is inaccurate due to overlooking this pretreatment.

Relative merits of three methods for the determination of pentosans is currently under study in an interlaboratory collaborative test program. The three methods are: The Tentative Method of Test for Pentosans in Cellulose (Aniline Acetate Colorimetric Method) (D 1438 – 56 T); Pentosans in Pulp (TAPPI T223 m-48); and The Determination of Pentosan Content of Rayon Pulps (Orcinol Method) (Swedish CCA-24).

Some eighty definitions of terms used in the cellulose field are being prepared. Correspondence with research workers throughout the world is being conducted to establish validity of these terms.

Schedule of ASTM Meetings

This gives the latest information available at ASTM Headquarters. Direct mail notices of all district and committee meetings customarily distributed by the officers of the respective groups should be the final source of information on dates and location of meetings. This schedule does not attempt to list all meetings of smaller sections and subgroups.

Date	Group	Place
Oct. 31–Nov. 1	Committee C-3 on Chemical Resistant Mortars	Suffern, N. Y. (Motel-on-the-Mountain)
Oct. 31–Nov. 1	Committee D-14 on Adhesives	Philadelphia, Pa. (Sheraton Hotel)
Nov. 7–8	Committee F-1 on Materials for Electron Tubes and Semiconductor Devices	Skytop, Pa. (Skytop Lodge)
Nov. 11	Southwest District (joint with Texas Soc. Prof. Engrs., ACS, AIChE, NACE, ASCE)	Houston, Tex. (Univ. of Houston)
Nov. 12	Ohio Valley District (joint with ACS and ASM)	Columbus, Ohio (Lincoln Lodge)
Nov. 13	Detroit District	Detroit, Mich. (Eng. Soc. Bldg.)
Nov. 14–15	Committee D-15 on Engine Antifreezes	Philadelphia, Pa. (Sheraton Hotel)
Nov. 15	Northern California District (joint with Nat. Assn. Power Engrs.)	San Francisco, Calif. (Slovenian Hall)
Nov. 18–20	Committee D-9 on Electrical Insulating Materials	Virginia Beach, Va. (Cavalier Hotel)
Nov. 19	Southwest District	New Orleans, La.
Nov. 19	Committee E-11 on Quality Control of Materials	Philadelphia, Pa. (Society Headquarters)
Nov. 20–22	Committee D-20 on Plastics	Virginia Beach, Va. (Cavalier Hotel)
Nov. 20	Southeast District	Columbus, Ga., and West Point, Ga.
Nov. 21	Washington District	Raleigh, N. C.
Dec. 2–3	Committee C-1 on Cement	Fortin de las Flores, Mex. (Hotel Ruiz Galindo)
Dec. 2–4	ASTM-ASME Committee on Effect of Temperatures on the Properties of Metals	New York, N. Y.
Dec. 5–6	ASTM-SAE Committee on Automotive Rubber	Detroit, Mich.
Dec. 5–6	Committee C-9 on Concrete and Concrete Aggregates	Fortin de las Flores, Mex. (Hotel Ruiz Galindo)
Dec. 5–6	Committee B-9 on Metal Powders and Metal Powder Products	Chicago, Ill. (Drake Hotel)
Dec. 9–13	Committee D-18 on Soils for Engineering Purposes	Mexico City, Mex. (Univ. of Mexico)
1958		
Jan. 13–15	Committee D-19 on Industrial Water	New Orleans, La. (Hotel Jung)
Jan. 23	Southern California District (joint with ASM)	Los Angeles, Calif. (Rodger Young Audit.)
Jan. 30	Northern California District (joint with ASME)	San Francisco, Calif. (Engineers Club)
Feb. 10–14	ASTM COMMITTEE WEEK	St. Louis, Mo. (Hotel Statler)

80 per cent of our members have sent in their instruction cards on the 1958 Book of Standards. Have You?
(These are needed urgently)

Your Committee Officers

A new series—to better acquaint BULLETIN readers with the men whose responsibility it is to direct the indispensable work of the ASTM technical committees.

Committee A-3 on Cast Iron

Chairman—D. E. Krause, executive director, Gray Iron Research Inst.

Vice-Chairman—T. E. Eagan, research metallurgist, The Cooper-Bessemer Corp.

Secretary—R. A. Clark, manager, foundry service, Electro Metallurgical Co., Division of Union Carbide and Carbon Corp.

Assistant Secretary—H. W. Lownie, Jr., chief, process metallurgy research, Battelle Memorial Inst.

Committee B-9 on Metal Powders and Metal Powder Products

Chairman—J. L. Bonanno, treasurer and chief engineer, The Lionel Corp.

Vice-Chairman—H. R. Biehl, The International Harvester Co.

Secretary—C. G. Johnson, vice-president, The Presmet Corp.

Committee C-3 on Chemical-Resistant Mortars

Chairman—Beaumont Thomas, chief chemist, Stebbins Engineering and Manufacturing Co.

Vice-Chairman—J. R. Allen, Experimental Station, E. I. du Pont de Nemours & Co., Inc.

Secretary—E. A. Reineck, technical service, The Quaker Oats Co.

Symposium on High-Temperature Strain Gages at Philadelphia

THE AERONAUTICAL Structures Laboratory of the Naval Air Material Center in Philadelphia, Pa., will hold a symposium on high-temperature strain gages at the Center on December 4 and 5, 1957.

Tentative plans call for the presentation of papers both mornings; a tour of the Laboratory's testing facilities on the first afternoon; and a panel discussion of the material presented in the technical papers is scheduled for the second afternoon.

The Aeronautical Structures Laboratory is currently engaged on research in elevated temperatures, and because all available strain gages have been found inadequate in the temperature range up to 1600 F, has undertaken development work in strain measurement at these high temperatures. Since many other Government and industrial laboratories are concerned with the same problem, it is hoped that the symposium will provide a useful exchange of ideas and help to prevent a duplication of effort in this important work.

While planning for the technical program is well advanced, anyone who feels he has a paper that would represent a substantial contribution is invited to bring it to the attention of the Aeronautical Structures Laboratory. Others who wish to attend the symposium should also apply to the Laboratory.

More Unsolved Problems . . .

Eight Cement Problems Outlined

As its contribution to the Society's project "Challenges in Materials Research," sponsored jointly by the Administrative Committee on Research and each of the technical committees of the Society, Committee C-1 on Cement has prepared a group of eight problems in the cement field.

Problems contributed by the technical committees are published from time to time in the BULLETIN and at intervals collected and published under the title *Challenges in Materials Research*. Wide interest in this collection of problems has been shown and many copies of the 1954 edition have been distributed free to all who have requested them The publication was last revised in August 1954, and the most recent published committee contributions appeared in the October 1956 BULLETIN from Committees B-9 on Metal Powders and Metal Powder Products and E-12 on Appearance.

It is hoped that the publication of these problems will stimulate contributions of problems from other committees either new ones, or revised and up-to-date statements of problems which have appeared before.

Following are statements of the eight problems on cement presented in the form recommended by the Administrative Committee on Research. Additional information may be obtained from W. S. Weaver, Canada Cement Co., Ltd., Phillips Square, Montreal 2, P.Q., Canada.

Plasticity of Cement Paste

Contributed by Committee C-1 on Cement

Problem:

Much work has been done over the years, so far without success, to develop a single test which would measure the ease of handling, placing, reworking or relocating and, finally, consolidating concrete without segregation or honeycombing. The quantity and character of the cement paste constituent are important factors in concrete placeability. It is the responsibility of the Working Committee on Bleeding, Plasticity, and Workability to define and, if possible, to devise a method of test for those properties of cement paste which control concrete placeability and workability.

A workable and placeable concrete is one consisting of well-graded, properly proportioned aggregates suspended in sufficient quantity of cement paste of suitable consistency to prevent particle interference and direct particle contact. With particle contact or excessive particle interference, concrete becomes "harsh" and hard to handle. Purposefully entrained air plasticizes cement mortar by reducing or eliminating particle interference (the "flexible ball bearing" effect) but stiffens the cement paste. Thus, a universally applicable method of test for plasticity of cement paste should probably be based on sand mortar and not paste alone.

However, since it is the character of the paste, and not the mortar, which is to be measured, the quantity of paste used in the test mortar should be sufficient to eliminate completely all sand particle interference effects. Also, the sand used should be properly graded in order to reduce cement paste content to a minimum consistent with cement paste—sand ratios in concrete. Obviously, too, the sand grains should be rounded and have low absorption to minimize the effect of particle shape and surface characteristics on plasticity and water requirement.

From this, it appears that the problem is to evolve a test to measure the elusive handling properties of a standard mortar containing the cement in question. But in order to measure such a property of cement paste or mortar, it must be properly defined. Actually, it seems to be the present consensus that more than one factor is involved in the measurement of workability and that all these factors will have to be determined separately to get a composite picture of the contribution of a given cement to workability of concrete.

Present state of knowledge:

Many workability factors have been mentioned and studied by previous investigators, as follows: plasticity, workability, placeability, fluidity or wetness, mobility, fatness, stickiness or cohesiveness, capacity for plastic deformation or plastic limit or deformability, shear resistance, yield point, harshness, segregation tendency, etc. Finishability, or the ease with which a concrete surface can be finished, is also sometimes considered a workability factor, while bleeding is considered a form of segregation.

A special selected bibliography on this subject has been prepared by H. Steinour of the Portland Cement Assn. A few copies are still available for interested parties. Reports of ASTM Committee E-1, Subcommittee 9 on Rheological Properties, will also be pertinent and helpful.

Questions that need to be answered:

1. How should the pertinent properties above listed be defined?
2. What tests and equipment should be used to measure the properties so defined?
3. Will one method of test be enough or will more be required to measure the properties of workability, plasticity, etc?

Workability of Masonry Cements

Contributed by Committee C-1 on Cement

Problem:

Progress on the development of an adequate specification covering the property of workability or plasticity of masonry cements (when used as mortars) has been delayed or possibly stopped by the failure to develop mechanical equipment or specialized instruments that can be used to judge the relative workability of masonry cement mortars. In present-day studies, the terms workability and plasticity are frequently used interchangeably. However, some investigators consider plasticity to be one of four factors included in workability.

Present state of knowledge:

Although research has been carried out to develop apparatus to measure the work done when mortar is deformed, the problem involves a measurement of the "adhesiveness" or "stickiness" of the mortar and other properties, in addition to a measurement of the ease of movement or placement of the mortar. Most effort and progress on this problem has been directed toward the measurement of the stress required to move or deform mortar.

The present specification for Masonry Cement C 91 includes a "Water Retention" or "Flow after Suction" test, but this measurement is considered to be related to workability and not a direct measurement of workability. The present state of knowledge on the workability of masonry cement mortars

is such that the judgment of the mason is relied upon almost entirely for the measurement of this property.

Questions that need to be answered:

Can the properties which the mason specifies as (*a*) ease of spread, (*b*) cohesiveness, (*c*) stickiness, and (*d*) body, be measured by mechanical means? It would be desirable to make these measurements while the mortar is under suction, comparable with that produced by the masonry unit. The "ease of spread" of mortar is usually determined by the mason over an absorptive surface, and a mechanical measurement of this property should show the effect of suction applied to the mortar.

Inasmuch as the relation of these properties in different mortars is not necessarily constant, it may be desirable to develop several different instruments in order to evaluate fully the workability or plasticity of a mortar.

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(3) G. C. Wilsnack, "Apparatus for Quick Determination of Plasticity of Masonry Cement Mortar," *Rock Products*, Vol. 54, pp. 114–117, Oct. 1951.

Evaluation of Cement Strength and Relationships to Concrete Strength

Contributed by Committee C-1 on Cement

Problem:

To develop test methods which will measure the rate and degree of strength development of hydraulic cement mortars under highly standardized laboratory conditions which will also allow prediction of the rate and degree of structural strength development in such mortars and in concrete under "field" conditions.

Present state of knowledge:

The resistance to tensile stress of a briquet having a 1-in. cross-section at the waist has been the classic mode of cataloging the strength-developing characteristics of hydraulic cement. This test is covered in ASTM Method C 190. As early as 1904, it was recognized that this tension test was not adequate. In 1912, a joint committee of the American Society of Civil Engineers, the ASTM, and the Federal Committee on Specifications for Cement, assigned to ASTM Committee C-1 the project of developing an adequate test for strength. The report of this study concluded in favor of a compressive strength test. Similar findings by later investigators led to the compressive strength test method as now specified in ASTM Method C 109 using 2-in. cubes. Although the weight of evidence accumulated through the years caused the Federal Government to drop the tension test in favor of the compression test in all specifications for hydraulic cements and the ASTM to drop the tension test in its specifications C 175 for air-entraining portland cement and C 91 for masonry cement, the tension test remains the preferred test in specification C 150 for portland cement.

Recognizing that the solution to the basic problem may not lie in either the "briquet" tension test or the "cube" compression test, the Working Committee on Strength has developed and tested recently a flexural strength test and a modification of the compression test which uses portions of beams as test specimens. These two methods have been accepted as tentative methods to permit further study.

Questions that need to be answered:

Which method of test will serve most accurately to predict the strength-gaining potential of hydraulic cements when used in "field" mortars and concretes?

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(3) T. M. Whiteside, "A Study of the Compressive, Flexural and Tensile Strengths of Ottawa Sand Mortars and their Relation to the Flexural and Compressive Strengths of Concrete," private report of the Portland Cement Assn. to the Working Committee on Strength of ASTM Committee C-1 on Cement, April 1953.

(4) M. A. Swayze, "The Testing of Cements for Inherent Strength, ASTM Bulletin No. 209, Oct. 1955, p. 27.

Critical Performance Test for Sulfate Resistance

Contributed by Committee C-1 on Cement

Problem:

The disintegration of concrete from contact with alkaline sulfate is a problem of long standing in many localities. The problem has been studied by many investigators during the past 60 years. The chemistry of the reactions is consequently well understood. Further information is required relative to the characteristics of cements and concretes that will provide resistance to the alkaline sulfates.

Present state of knowledge:

The problem of sulfate resistance is recognized in the ASTM Specifications for Portland Cement (C 150) and for Air-Entraining Portland Cements (C 175). In these specifications the sulfate-resistant cements are defined in terms of chemical limitations. The chemical limitations in the current specifications appear to be adequate for the selection of portland cements that will produce concrete having a high resistance to sulfate waters. Good quality concretes made with sulfate-resistant portland cements have given excellent performance under adverse conditions of alkaline sulfate exposure. However, such chemical limitations are not applicable to hydraulic cements other than portland cements, and they do not make allowance for new or improved cement manufacturing procedures that may produce sulfate-resistant cements.

Questions that need to be answered:

A performance test for the potential sulfate resistance of cements and applicable to all classes of hydraulic cements would be desirable. Such a test would provide a more adequate procedure for the selection and testing of cements and would provide a means for research that might well lead to the development of cements of even greater sulfate resistance than those now available.

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(2) F. R. McMillan, T. E. Stanton, I. L. Tyler and W. C. Hansen, "Long-Time Study of Cement Performance in Concrete." "Concrete Exposed to Sulfate Soils," Special Publication, Am. Concrete Inst., *Bulletin No. 30*, Research Laboratories of the Portland Cement Assn. (1949).

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(4) David Wolochow, "Determination of the Sulfate Resistance of Portland Cement," Appendix, Report of Committee C-1, *Proceedings*, Am. Soc. Testing Mats., Vol. 52, p. 250 (1952).

(5) "A Performance Test for the Potential Sulfate Resistance of Portland Cement," ASTM Committee C-1, Working Committee on Sulfate Resistance, ASTM Bulletin No. 212, Feb. 1956, p. 37.

Specification Limits for SO_3 Content of Portland Cement

Contributed by Committee C-1 on Cement

Problem:

Specifications for portland cement have, in the past, maintained maximum limits on the amount of sulfuric anhydride (SO_3) in cement. This has been determined by chemical analysis made upon the cement. The maximum limit has been felt necessary to guard against expansions which develop in hydrated portland cement pastes subjected to storage in moist conditions when the SO_3 content of the cement is abnormally high. Researches have shown that cements of superior strength and greater volume constancy are secured when gypsum is added to cement in an optimum amount. The optimum amount for many cements has been found to be higher than permitted in the past by the maximum allowable amount of SO_3, and also in many cases much lower than this figure. Arbitrary chemical limitations upon SO_3, therefore, were abandoned in ASTM Specifications for Portland Cement, C 150 and C 175 and a performance type of test substituted which, it was hoped, would permit the optimum amount of gypsum to be used without permitting an excessive amount.

This test, (Method of Test for Calcium Sulfate in Hydrated Portland Cement Mortar C 265), determines the presence of calcium sulfate in portland cement mortar after it has hardened in the moist room for 24 hr. The amount of SO_3 found by chemical analysis to be present in a water extract of pulverized mortar indicates the extent to which the gypsum has reacted in the hydration process. It has been found that, when a cement contains an optimum amount of gypsum the calcium sulfate will have reacted completely with the cement at the end of 24 hr of normal hydration; a solution saturated with calcium hydroxide and calcium sulfoaluminate, and devoid of gypsum, has an SO_3 content of less than 0.01 g per liter. Therefore, if excessive quantities of gypsum are interground with the cement, unreacted gypsum will be indicated by a greater presence of SO_3 in the water extract. It has also been proposed that the extraction test, performed at a time slightly in advance of 24 hr, could be used to indicate whether insufficient gypsum for optimum results has been used. At this earlier period it would be desired to show some unreacted gypsum by the presence of SO_3 in the extract.

The principle described above has universal acceptance, but, unfortunately, Method C 265 has not proved to be reproducible with sufficient accuracy to make it a practical test for delineating both minimum and maximum limits on SO_3. Consequently in 1955, Committee C-1 returned to the use of arbitrary maximum chemical limits for SO_3 in cement. Reference should be made to ASTM Specifications C 150 and C 175.

As presently written, the test needs refinement so that its results are more reproducible, before it could be used in specifications to insist that some proper minimum amount of gypsum be used in cement as well as to insure that the proper amount has not been harmfully exceeded.

Present state of knowledge:

It is well established that an optimum amount of gypsum is desirable in cement. This optimum amount is different for each cement and, therefore, arbitrary limits upon the amount of SO_3 found in cement by chemical analysis (when these limits are set too low) often prevent use of the proper amount of gypsum. Excessive amounts of gypsum do contribute to latent expansion of mortar under moist curing and should be limited but, as the amount which is excessive is related to the optimum amount, fixed limits on SO_3 content of cement are technically unsupportable.

Gypsum controls the early hydration of cement and, when added in the correct amount, regulates the rate at which the early hydration proceeds. The gypsum reacts with hydrating tricalcium aluminate and, when present in the proper amount, this reaction is completed in about 24 hr of normal hydration. If the gypsum is exhausted prior to this time, or if present in amounts which prolong this reaction period, the hydration reactions are evidently not regulated to the best advantage.

The presence of SO_3 in the water extract from pulverized mortar after it has been cured 24 hr indicates gypsum in excess of the optimum quantity. Method C 265 has not been entirely satisfactory, however, since consistent results have not been obtained by different laboratories working with the same sample. It appears that slight variations in the initial temperature of the mortar and during its curing materially affect the rate of reaction of gypsum with cement so that slightly different results are secured at the end of 24 hr. However, the results are accurate enough that test errors would not permit such an excessive amount of gypsum as to cause latent expansion of mortar or concrete.

Questions that need to be answered:

1. The test method and technique need to be improved so that results can be reproduced within ± 0.10 g per liter.
2. In lieu of above, a new type of test should be devised to indicate when a cement contains the optimum amount of gypsum.

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(3) Tentative Method of Test for Calcium Sulfate in Hydrated Cement Mortar, C 265 T, 1955 Book of ASTM Standards, Part 3, p. 66.

(4) W. C. Hansen, "The Properties of Gypsum and the Role of Calcium Sulfate in Portland Cement," ASTM BULLETIN No. 212, Feb. 1956, p. 66.

Effect of Aging of Cement

Contributed by Committee C-1 on Cement

Problem:

Questions have repeatedly arisen concerning the effect of aging of cement on fineness, strength, and on the workability, durability, and other properties of concrete. The initial temperature of concrete is known to have a marked effect on the strength of concrete, and this initial temperature is affected considerably by the temperature of cement used in its manufacture. Cement in bulk shipments has frequently arrived at the job at temperatures in excess of 200 F. Such hot cement has given rise to speculations over the quality of the resulting concrete and the suggestion that concrete quality might be improved if the cement were cooled during its manufacture or allowed to cool and age prior to delivery.

Present state of knowledge:

In past years, prior to the development of autoclave tests to detect latent unsoundness of poorly burned cements, it was customary to season cement for some period before offering it to the trade. This cured it of much of its expansive tendencies. Even today, cements which fail to meet the autoclave expansion test will frequently pass the test if it is repeated at a later date, provided that the expansion is due to the presence of free lime rather than excess magnesia. Aging of cement, therefore, can be considered to be beneficial if it is not exposed to moisture or the elements during the seasoning period.

False set has been frequently observed with cement which is delivered to a job at considerable temperature. The strengths of concrete cast during

summer months have been notably below that of concrete made with the same ingredients during cooler months of the year. This has been definitely related to the initial temperature of the concrete. However, speculation directs some suspicion toward the use of hot cement which is more prevalent during warm weather.

Cement which is stored in sealed containers is slated to show greater fineness as determined by sieves during aging. On the contrary, its fineness as determined by turbidimeter measurements, decreases. It is also established that some cements which have aged in sealed storage produce more workable concrete than when first used. Freezing and thawing tests conducted on concretes made from the same cement, after different periods of aging, indicate that up to eight months, more durable concrete results if the cement is aged before use in concrete.

Questions that need to be answered:

1. Determine whether cement which is kept cool (not over 150 F) during manufacture produces concrete of different quality than cement which is stored in silos at much higher temperature. This would include studies on the false set characteristics of such cements.

2. Determine the effect of age of cement on its workability in concrete.

3. Determine the effect of age of cement on its physical characteristics.

4. Determine effects of age of cement on various properties of concrete made therefrom.

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(7) Hartwell, "Effect of Storage Upon Setting Qualities of Cement," *Concrete* (1904) 5(4)058.

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Evaluation and Classification of Pozzolanic Materials; Mechanism of Pozzolanic Action

Contributed by Committee C-1 on Cement

Problem:

There is no source of integrated authentic technical information on the properties of pozzolanic materials, alone or in blends with other cements. There is a need for such information and data. Likewise, a more complete explanation of pozzolanic action is very desirable.

Present state of knowledge:

The Babylonians and Romans used pozzolanic cements in their construction projects. Some of these structures still stand. The science was lost for many centuries. In recent years, because of special properties obtained through their use, interest has been renewed in the technology of pozzolans. The lack of research data is a barrier to their more frequent use.

Questions that need to be answered:

1. Can a simple and reliable method for the evaluation of pozzolans for use in concrete be developed?

2. Can a classification of pozzolans be established based on their properties and availability?

3. What is the most acceptable mechanism of pozzolanic action in concrete?

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Autoclave Expansion of Cement and Concrete Soundness

Contributed by Committee C-1 on Cement

Problem:

The autoclave expansion test of neat cement bars is undoubtedly an excellent accelerated soundness test for portland cement. Well burned clinker of normal composition, finely pulverized, will in general produce cement which will meet the present ASTM limit. Information is lacking, however, on the exact relationship of cement autoclave expansion and the expansion characteristics of concrete under exposure conditions, both normal and abnormal.

Present state of knowledge:

The current ASTM Specification for Portland Cement, (C 150) contains a maximum limit of 0.5 per cent autoclave expansion of portland cement when tested according to ASTM Method of Test C 151. During World War II, this requirement was relaxed to 1.0 per cent. The present Canadian Specification permits 1.0 per cent for an essentially identical determination.

On the other hand, excellent concrete has been made in this country and elsewhere using portland cement which would have exceeded an autoclave expansion of 0.5 per cent. The Le Chatelier test specified in the British Standard for Portland Cement tolerates an expansion which corresponds to an autoclave expansion greater than 5.0 per cent. British-made cement has been shipped for construction jobs all over the world and many countries either specify BS 12:1947, the current British Standard, in purchasing cement from foreign sources, or have adopted the same Le Chatelier test in their own specifications.

Two main factors contribute to autoclave expansion of cement. Reference is made to free lime and magnesia content. The problem may require research into the effect of these two factors independently or in combination.

Questions that need to be answered:

1. What are the relationships between cement autoclave expansion and expansion of concrete?

2. Do water-cement ratio or aggregate proportions influence these relationships?

3. Is the present ASTM requirement excessively stringent and if so, what maximum limit could be established to insure adequate consumer protection?

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Controlled Thermal-Shock Testing of Glass-Cloth Laminates*

By J. H. BENO, A. M. DOWELL, and E. F. SMITH

When resin-glass-cloth laminates are subjected to rapid heating, such as occurs in supersonic flight, delamination and consequent impairment of mechanical strength may result

IN THE DESIGN of aircraft and missiles, resin-glass-cloth laminates are frequently specified because of their favorable strength to weight ratio and good dielectric properties. Such laminates are particularly suitable for missile radomes. A radome must withstand loads and temperatures imposed by flight without impairment of its mechanical or electrical properties. In the course of another investigation it was found that, in some cases, rapid heating caused delamination of a thin-wall missile radome. To develop a radome that would not delaminate under service conditions, it was essential that a laboratory method for simulating the thermal shock of aerodynamic heating be found.

Three methods for producing a controlled thermal shock were investigated: forced draft heating, infrared radiation, and immersion in a molten-metal bath. Of these, the molten-metal-bath method has been found most suitable for the convenient and rapid simulation of aerodynamic heating. By this method, laminate samples can be subjected to specific reproducible conditions of thermal shock. The molten-metal bath equipment and method are described below, and the results of several studies are given to illustrate the application of the method in the study of some aspects of delamination.

Equipment

The molten-metal bath and auxiliary equipment are mounted on a portable stand as shown in Fig. 1. The electrically heated bath, 10 in. in diameter by 14½ in. deep, is filled with approximately 350 lb of Cerromatrix, an alloy of antimony, tin, bismuth, and lead. The molten bath is agitated by a stainless steel propellor driven by the ¼ hp motor mounted next to the bath. A well, immersed in the bath, contains the sensing elements of instruments which record and control the bath temperature. The bath temperature can be controlled to ±2 F. Test specimens are immersed and retracted by means of the solenoid-operated air valve and piston visible in the upper part of the picture. The piston can be positioned over the metal bath or over a cooling bath (silicone oil) shown in the figure on a small platform above the stirrer motor. The cooling bath is a can of one gallon capacity; no attempt is made to control the cooling bath temperature. In either position of the piston, one of two microswitches is actuated when the

THE AUTHORS are members of the Technical Staff, Research Laboratories, Hughes Aircraft Co., Culver City, Calif.

J. H. BENO, assistant head, Nuclear Electronics Department, has had 14 years' experience in testing, instrumentation, and dielectric materials development. For the past five years he has been engaged in materials evaluation for missile applications.

A. M. DOWELL, Applied Physics Group, Radome Department has had 5 years' experience in mechanical testing of plastics and the development and application of test methods simulating aerodynamic heating.

E. F. SMITH, senior staff physicist, Radome Department has had 13 years' experience in the development of test equipment and the measurement of physical properties of plastics. Engaged in the evaluation of materials for missile applications for the past three years.

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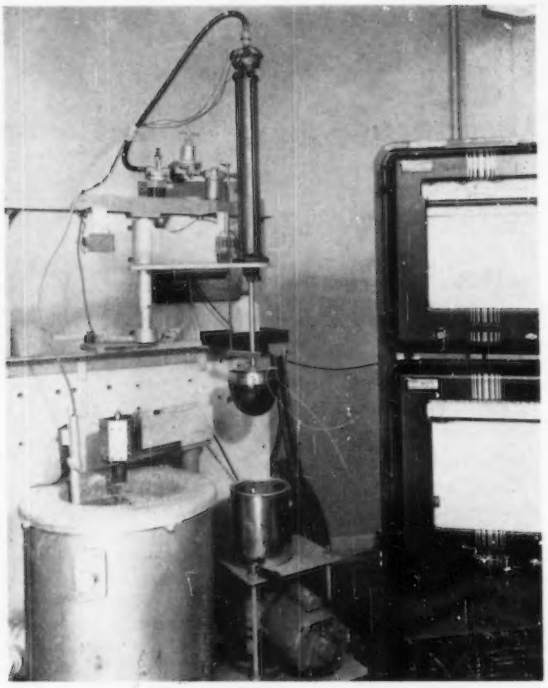


Fig. 1.—Molten metal bath apparatus with test specimen in position.

piston moves down to immerse the specimen. Each microswitch operates a time-delay relay which is set to give the desired immersion time; when the set time has elapsed, the timer operates the air valve and the piston retracts the sample. In the picture, a typical specimen may be seen above the cooling bath. The specimen may range in size from a flat plate 6 in. in diameter to a cylinder 8 in. long and 6 in. in diameter.

Test Method

A test specimen is subjected to thermal shock simply by immersion in the molten-metal bath. The thermal shock is dependent on the temperature of the bath, the time of immersion, and the rate of cooling after retraction from the bath.

In simulating the thermal shock of aerodynamic heating, theoretical values of interior and exterior temperatures are first calculated for the laminated parts under consideration. These calculations are based on the concept of a flat plate moving through a fluid, and the resulting equations are solved by numerical application of the Schmidt finite-difference method using time increments of 0.3 sec. The theoretical time-temperature curves thus obtained define the particular thermal shock conditions which must be simulated.

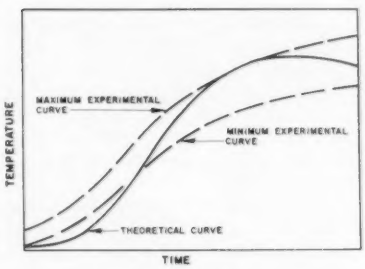
In a preliminary test, a specimen is fitted with carefully bonded thermocouples for the continuous recording of inner and outer surface temperatures, immersed in the molten-metal bath for a fixed time at a constant bath temperature, and then allowed to cool. The recorded time-temperature curve is compared with the theoretical curve, the bath temperature and immersion time are adjusted to correct for differences, and the thermal-shock procedure repeated until the two curves match. Where the cooling rate in air is slower than that required by the theoretical curve, additional cooling is provided by immersion in silicone oil. When the testing cycle has been established for a given laminated component, tests can be conducted easily and rapidly. The time-temperature curves are highly reproducible because both immersion time and bath temperature are readily controlled.

Several precautions, however, must be observed. The specimen must be shielded from radiant heat prior to immersion; this is done by placing a polished metal plate between the bath and the specimen. The exterior surface (that exposed to aerodynamic heating) must be in intimate contact with the molten metal, but the metal should not be allowed to spill over onto the interior surface. This is prevented, in testing radomes, by attaching the radome to the piston with a tightly fitted cap over the base of the radome and by not immersing the radome to its full length; for flat laminates the specimen is floated on the surface of the molten metal in an open-sided cage. Placement and attachment of thermocouples on the test specimen is critical since the theoretical values are calculated for specific positions on parts in the air stream. To reduce temperature measurement errors, thermocouples having small mass are bonded with a thin film of resin to the test specimen. The bonding resin is identical with that used in the test specimen.

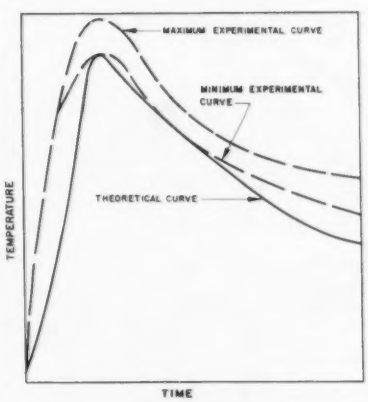
Application of Test and Results

Thermal shock testing with the molten-metal-bath apparatus has been used to evaluate the resistance of missile parts to aerodynamic heating, and to investigate the effects of humidity and processing parameters on the thermal shock resistance of phenolic-glass-cloth laminates.

Aerodynamic heating is easily simulated as shown in Figs. 2 and 3. The theoretical aerodynamic heating curves (solid line) show radome temperatures calculated for specific conditions of

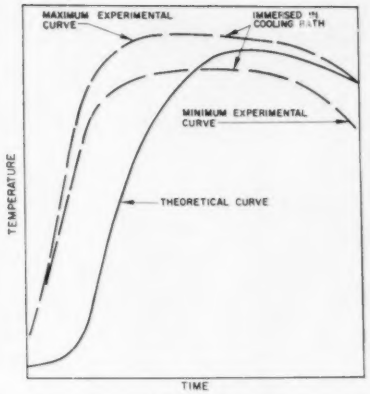


(*a*) Inner

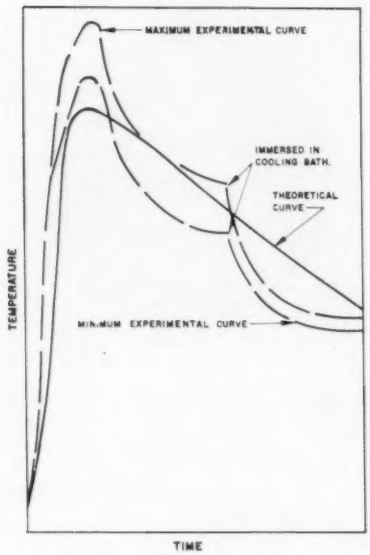


(*b*) Outer

Fig. 2.—Duplication of a surface temperature.



(*a*) Inner



(*b*) Outer

Fig. 3.—Duplication of a surface temperature.

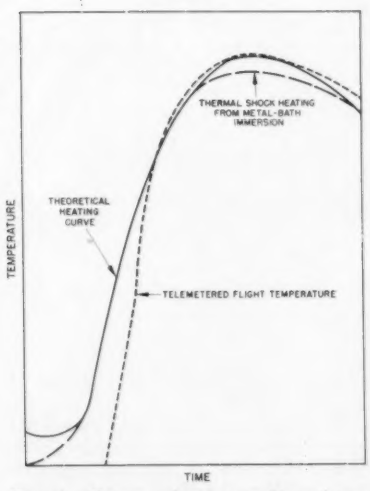


Fig. 4.—Curves showing radome inner surface temperatures, theoretical and experimental.

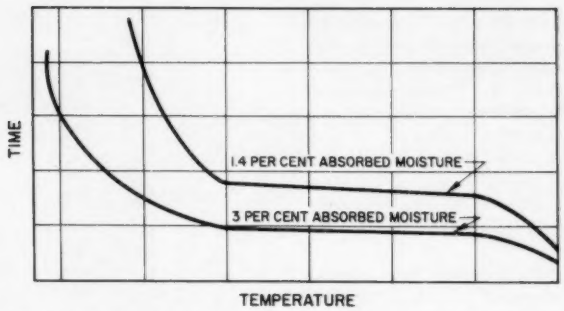


Fig. 5.—Delamination time and temperature as a function of absorbed moisture.

missile flight. The upper and lower curves (dotted lines) were each plotted from the experimental data of single test runs and represent the upper and lower extremes of radome temperature obtained for a given metal bath temperature. Telemetered flight data on radome temperatures, calculated theoretical values, and temperatures recorded for test radomes in the molten-metal bath have been compared and found to be in excellent agreement as shown in Fig. 4. Therefore, the behavior of a laminated component under specific conditions of thermal shock in the molten-metal bath is a valid measure of the component's resistance to corresponding conditions of aerodynamic heating.

The controllability of the molten-bath thermal shock method facilitates its application to evaluation of process parameters. When, for example, laminated specimens that differ only in their postcure history are tested under identical thermal shock conditions in a series of tests, the effect of postcure on resistance to thermal shock can be readily evaluated from visual observation of delamination or blistering. It has been established that if a laminate is postcured to a temperature exceeding the highest temperature reached during thermal shock, no delamination occurs unless the laminate has absorbed moisture through conditioning at high relative humidity.

The interrelationships of moisture content in the laminate, postcure parameters, and elapsed time to delamination during constant immersion in the metal bath are given in Fig. 5 and Table I. Figure 6 shows the blistering that occurs in both radomes and flat laminates.

The test apparatus has also been used to investigate the mechanism by which these delamination failures occurred. For this purpose, resistance strain gages were bonded to test radomes. When a dry radome is immersed in the bath, a tensile stress appears on the inside surface due to the thermal gradient across the radome wall. This stress reaches a maximum and then decays. In a radome that has been conditioned at high relative humidity, the tensile stress appears, reaches a maximum, approximately

TABLE I.—AVERAGE DELAMINATION TIMES FOR FLAT LAMINATES.

	Bath Temp.	Dry	1.4 per cent Absorbed Moisture	3 per cent Absorbed Moisture
Low Temperature Postcure	*a*[a]	60 Sec[b]	60 Sec[b]	12.5 Sec[b]
	b	60 Sec[b]	22.0 Sec	6.3 Sec
	c	60 Sec[b]	9.2 Sec	4.3 Sec
	d	13.9 Sec	6.6 Sec	5.1 Sec
	e	9.9 Sec	3.2 Sec	2.7 Sec
High Temperature Postcure	*a*	60 Sec[b]	60 Sec[b]	60 Sec[b]
	b	60 Sec[b]	60 Sec[b]	60 Sec[b]
	c	60 Sec[b]	60 Sec[b]	7.8 Sec
	d	60 Sec[b]	60 Sec[b]	8.7 Sec
	e	60 Sec[b]	7.2 Sec	3.2 Sec

[a] Letters denote corresponding bath temperatures in increasing sequence.
[b] No delamination.

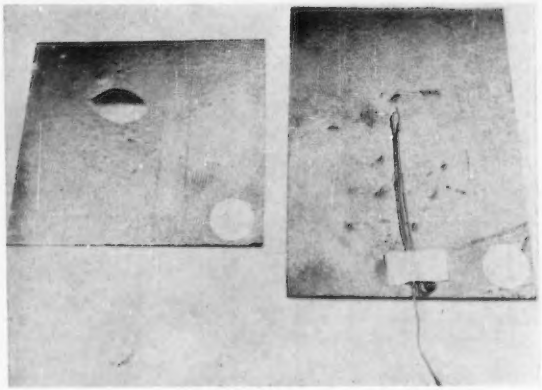
equal to that observed with dry radomes, decreases, and then increases again to a very much higher maximum as shown in Fig. 7. The second maximum is interpreted as being due to pressure generated within the radome wall by water vaporization, and it is this force that causes blistering in the heating tests. Similar stress patterns were also observed in data telemetered during flight.

From this brief discussion the possibilities of the molten-metal-bath test method for laboratory exploration of problems associated with thermal shock become apparent.

Summary

A method for controlled thermal shock testing, that is capable of simulating aerodynamic heating, has been developed which makes use of a molten-metal bath as the heating medium. This method is preferred over the other methods tried because of its convenience and controllability.

The equipment and methods described are useful in evaluating (1) the resistance to thermal shock of completed assemblies under a variety of simulated flight conditions, (2) the effect of processing variables on the tendency of laminates to blister, and (3) the effect of environmental conditions on laminates subjected to rapid heating. This equipment has also been used in a study of the mechanism by which laminates fail when subjected to severe thermal shock.



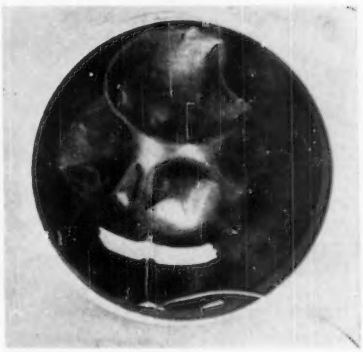


Fig. 6.—Examples of delamination in laminates after immersion in metal bath.

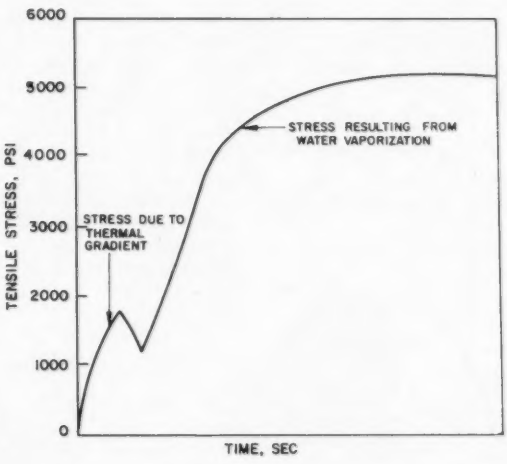


Fig. 7.—The development of stress in a heated laminate.

DISCUSSION

MR. C. R. STOCK[1]—I should like to ask two questions. One is, have you any toxicity problems with the bath? Secondly, have you found by a study of moisture content of the laminate some rather well defined maximum limits of moisture content that can be tolerated?

MR. A. M. DOWELL (*author*).—At the present time we have no toxicity problem. We are working in a large, open area and we have not experienced any toxicity effects.

The answer to the second part I am afraid is going to be in the realm of classified information. I will say, however, that we have good reason to expect that there is a maximum moisture content above which parts will delaminate.

[1]Group leader, physical measurements group, American Cyanamid Co., Stamford, Conn.

Creep of Glass-Reinforced Plastics

By S. GOLDFEIN

An interim report on development of a method of determining the creep properties of glass-reinforced plastic laminates by short-time or static tests of their properties at temperatures up to 500 F

CREEP may be defined as the slow deformation or elongation of a material subjected to a constant stress. The total creep of a material which has been deformed beyond its yield point is usually reported as the sum of the short-time deformation which is elastic and its long-time deformation beyond the yield point, which is plastic. Creep has been found to be a function of temperature and such environmental factors as may affect the strength of the material, such as water, chemicals, solvents, weathering, etc.

Creep is usually reported in the form of graphs containing curves of deformation *versus* time at various stress levels.

Much work has been done not only in attempts to derive formulas or mathematical relationships to describe what is happening during the creep process, but also allow the prediction of total creep after certain material constants have been derived (**1,2,3,4,6,12**).[1]

These formulas fall generally into the same pattern:

$$\epsilon = \frac{S}{E_1} + \frac{S}{E_2}(1 - e^{-t/\lambda_2}) + \frac{S}{E_1}\left(\frac{t}{\lambda_1}\right) \quad \ldots(1)$$

Total deformation = instantaneous elastic deformation plus the retarded elastic deformation (primary creep) plus the viscous flow (secondary creep). . . . . (2)

where:

ϵ = total deformation,
S = stress,
E_1 = elastic modulus,
E_2 = elastic modulus allied with viscous element,
t = time, and
λ_1, λ_2 = relaxation time for primary and secondary creep, respectively.

Equation 1 is sometimes used in the form:

$$\epsilon = \epsilon_0 + v_0 t - \frac{c}{\alpha} e^{-\alpha t} \quad \ldots(3)$$

where:

ϵ = total deformation,
ϵ_0 = the instantaneous elastic deformation,
v_0 = the minimum creep rate, and
c, α = constants depending on material, stress, and temperature.

These equations suffer from the same defect, namely, that they require long periods of time to determine minimum creep rates and material constants.

Robinson *et al* (**4**) derived a method of determining creep of metals by tests performed at constant strain rates. Khosal and Findley did this for a grade —C canvas laminate (**5**). In reference (**5**) although the results were of the right order of magnitude, the predicted rate of creep was too high. In addition, "the method was laborious and required a high degree of precision in the observations in order to secure an accurate prediction of creep." No provision was made in any of the formulas to include temperature as a variable.

Arrhenius (**13**) showed that the rate at which certain processes progress is related to temperature by the equation:

$$r = Ae^{-Q/RT} \quad \ldots(4)$$

where:

r = rate,
A = constant,
e = natural logarithm base,
Q = activation energy for process,
R = gas constant, and
T = absolute temperature.

This equation known as the "rate-process" or "decay law" has been shown by many investigators to be applicable to creep where r is the rate of creep.

Larson and Miller (**9**) showed that a simplification of the rate process law was applicable to rupture stresses and creep of most metals and alloys at high temperatures. In this simplification, a master rupture curve in which rupture stress was the ordinate and K which was equal to

$$T\,(20 + \log t) \quad \ldots(5)$$

was the abscissa used (T = absolute temperature, t = time under constant stress). Knowledge of any two of the variables allowed the third to be readily determined. Substitution of r (creep rate) for t in Eq 5 allowed the calculation of creep.

The author has shown (**7**) that the Larson-Miller parameter was also applicable to rupture stresses in glass reinforced plastics for tensile and compressive properties. He has also shown (**8**) that a steady-load-static-time equivalent (SLTE) of 10^{-4} hours allowed static tests at elevated temperatures lasting a few minutes to be used in predicting rupture stresses for the same materials for long periods of time and under special environmental conditions. The SLTE represented a constant-load-time which could be substituted for t in Eq 5, which was used to set up the master rupture curve. It took cognizance of the fact that the total elapsed time required to rupture a material exposed to an increasing stress, bore a definite relationship to the time which would be required to rupture the same material under a constant stress.

S. Goldfein, chief, Plastics Section, Materials Branch, U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va., is a chemical engineer with a background in many types of plastic materials and fabrication techniques. In the last few years he has exerted much effort in elucidating the time-temperature relationships which exist for rupture strength and creep in glass reinforced plastics.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

Investigation

Theory

It is theorized that the creep properties of a glass-reinforced plastic laminate may be calculated from its tangent modulus properties at elevated temperatures. Specifically, if a representative master modulus curve is drawn (Fig. 1) where the tangent modulus is the ordinate and T $(20 + \log t)$ is the abscissa (T is absolute temperature in deg Fahr and t is total time in hours the material is under test), then the total deformation

$$l = \frac{S}{E} \quad \ldots\ldots\ldots\ldots (6)$$

where:

l = total elongation or deformation,
S = stress, and
E = tangent modulus.

Tangent modulus here is defined as the modulus at stress S. It is calculated by drawing a tangent to the stress-strain or load-deflection curve at any stress S and using the slope to calculate the modulus as is performed in common practice. At low stress levels where the stress-strain curve is a straight line, the tangent modulus as defined here is identical with the commonly accepted meaning of the term.

The reasoning behind this is as follows:

A total deformation obtained during a modulus determination at high temperature can be made to match a total deformation obtained during creep at a lower temperature. Figure 1 shows how this is accomplished. The parameter K (Eq 5) is the abscissa and the tangent modulus E is the ordinate in Fig. 1. Equation 6 relates tangent modulus E to stress and strain. At any particular set of temperature and time conditions producing, for example, the parameter K_4, there is a corresponding tangent modulus E_4.

The tangent modulus, under constant stress, gradually decreases in accordance with Eq 4—the rate process law. Examining it from a mechanistic point of view, since modulus is a function, among other things, of bond angles and distance between atoms and molecules, as a material is stretched the modulus will decrease. Tangent modulus E_4 determinable by means of a test at some elevated temperature also varies as Eq 6 (stress *versus* strain). The strain as calculated in Eq 6 must therefore be equal to the creep experienced by the material under the different set of conditions of time and temperature.

Since most stress-strain curves of glass-reinforced plastics are curved to some extent, the tangent modulus will vary with the stress. This is particularly true at high temperatures. Most accurate results will be obtained, therefore, if the master modulus curve is drawn from stress level data close to or equal to the stress required. If a large number of data are to be obtained at a number of stress levels, a number of master modulus curves may be drawn on one finger, and resort may be made to interpolation, if necessary.

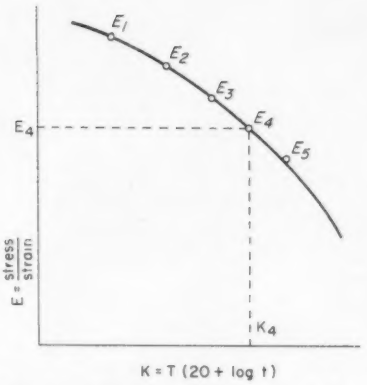


Fig. 1.—Representative master modulus curve.

The parameter K (Eq 5) has been found to describe both tensile and compressive rupture relationships with time and temperature for glass-reinforced plastics (**7**). The time t, however, refers to a steady load time during which the material is under constant load or stress. Attempts to use t values obtained during a rupture test during which the stress increases steadily will introduce large errors in the results. It was found that a steady-load-time-equivalent (SLTE) of 10^{-4} hours for such rupture tests with these materials produced good results (**8**). In setting up the master rupture curve, therefore, the value 10^{-4} hours for t should be used for all the moduli data obtained at elevated temperatures. Although the SLTE will vary with the rupture strength and temperature, the effect of considering the SLTE to be constant will introduce only minor errors.

Creep Calculation Procedure

A master modulus curve in which modulus was the ordinate and $K = T$ $(20 + \log t)$ was the abscissa was drawn. The modulus was calculated using those parts of the stress-strain curves in which the stress level was close to the working stress used to produce the creep. The steady load static time equivalent (SLTE) of 10^{-4} hours for t was used in the parameter for all the static tests (**8**) at the different temperatures.

1. *Tensile Creep.*—Given the temperature and time of creep the k value was calculated. The corresponding equivalent modulus was taken from the master tensile modulus curve. The creep was calculated using the formula $l = \epsilon =$ stress/modulus, where l is strain and ϵ is creep. Creep is defined here as total deformation at time t.

2. *Flexural Creep.*—This was calculated in the same manner as the tensile creep except that the modulus formula in bending $E = (L^3/4bd^3)$. (P/l) was combined with the flexural stress formula $S = 3PL/2bd^2$ to form $E = SL^2/6dl$ where S is stress, L is span length, d is thickness of specimen, and l is the total deflection at time t.

In the data analyzed the span length of the specimen tested was 2 in. The thickness was approximately 0.1 in.

Creep ϵ then becomes $6.66S/E$.

Creep Calculation Procedure Used When Creep at One Stress Level Was Available

This method was used when no modulus data were available. In the case of tensile creep, tensile equivalent moduli were calculated by dividing the stress by the creep throughout one stress level. Master modulus curves were then drawn and used to calculate creep at other stress levels. The same procedure was used to draw the master flexural modulus curve. Flexural creep was calculated using the method described in the previous paragraph.

Source of Experimental Data

No experimental work was done in this laboratory. Data were obtained from an Air Force Report No. 6172 (**10**) of work done at Battelle Memorial Institute and current work presently being done at Forest Products Laboratory (**11**).

The results of the investigation are found in Tables I to XI.

Discussion

Use of Modulus Data at High Temperatures

In order to prove the theory outlined, the modulus of elasticity at elevated temperatures of a number of glass-reinforced plastics, as well as creep data for these laminates, were required. In addition, the moduli had to be the moduli at the stress levels used in the creep experiments. There is a dearth of information on the subjects. Only one report (**10**) (USAF Technical Report 5172—Battelle Memorial Institute) was found to have the required information, and then in sketchy form. A large part of the data could not be used because of obvious inaccuracies. These inaccuracies consisted for the most part in decreases in ob-

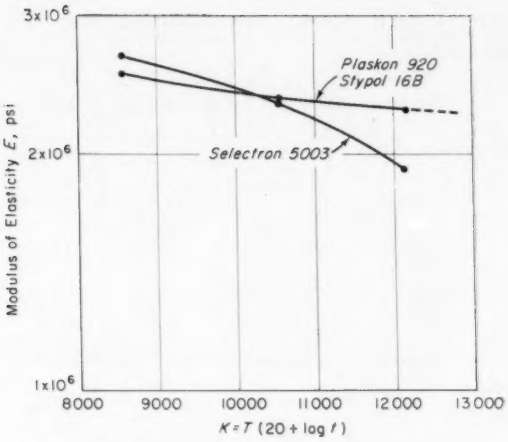


Fig. 2.—Master modulus curve for polyester laminates; secondary tensile moduli.

Note—SLTE of 10^{-4} hr used for t in setting up curves

served creep with increases in applied stresses and temperatures. It should have been the other way around. In that report only three points per curve were available to form two curves representing three laminates (Fig. 2).

Of 13 specimens comprising three plastic laminates (Plaskon 920, Stypol 16B, and Selectron 5003 all with 181 glass cloth, and 114 finish) which were tested, only eight were capable of being evaluated because of insufficient data. Five of the eight calculations agreed with the observed results within 6 per cent. Two calculations were between 10 and 11 per cent (one of which was obtained by extrapolation). One calculation was off by 26 per cent.

Table I shows the original data taken from reference (10) together with the calculated values of K used to draw Fig. 2.

Only secondary moduli of elasticity were used, since the laminates were subjected to stress levels closer to the secondary proportional limits than to the primary limits. Both primary and secondary moduli of elasticity were presented corresponding to two sets of slopes which were noticeable in each stress-strain curve. The proportional limits for the moduli are shown in Table I.

The results were thus promising, but there was still an extreme paucity of data.

Use of Long-Term Creep Data at Room Temperature

A great many creep data were available, some up to 10,000 hr, in work being done at Forest Products Laboratory for the Bureau of Ships (11). In this work, both polyester and epoxy resin glass laminates were tested at room temperature in tension and flexure, both wet and dry. No moduli data were available at high temperatures. Just as it was possible, however, to calculate long-term creep at room temperature from moduli data at high temperatures, so is it possible to do the reverse: calculate modulus data at high temperatures from long-term creep data at room temperature. Details for this procedure were outlined in a previous paragraph. Having used data at one stress level to set up the master modulus curve, the curve may be used to calculate creep at different stress levels for long periods of time, provided the stress-strain curve in the designated stress levels is a straight line.

The data were presented as creep for the time periods 0.1, 1, 10, 100, 1000 and 10,000 hr at room temperature. It was not necessary to draw any master modulus curves since all the creep data were reported at specified time intervals of multiples of 10, and since the temperature was held constant throughout the tests, the K values would be identical. Table III shows the data so obtained in tabular form.

A large majority of the tests indicated excellent agreement between the observed results and those obtained by calculation. The results appeared to be equally good for both polyester and epoxy laminates, wet and dry, when tested either in tension or flexure.

There appeared to be, unfortunately, a large proportion of obviously faulty specimens or tests. Some were easy to spot by examination of their 0-hr elongations. These were the immediate elongations which the specimens experienced when first loaded. As the applied stress was increased, the 0-hr elongation should have also increased proportionately. If specimens exhibited decreases in elongations with increases in stresses the data from such tests were not considered reliable. If two or more 0-hr elongations were closer or farther apart than their difference in applied stress warranted, there was an error somewhere.

Tensile Creep–Selectron 5003 Laminates

Using specimen 5 as a reference standard, only four of the remaining eight specimens could be evaluated. Of these specimens, 7, 8, and 9 gave excellent results. Table IV shows that of the nine specimens tested, two of the 0-hr elongations decreased rather than increased as the stress increased. A study of the first four specimens (1 to 4) shows that their 0.1 hr observed elongations are hopelessly mixed (0.819, 0.840, 0.736, 0.822). Thus, in addition to specimen 3, at least one other specimen was defective. As it turned out, only specimen 2 was in the proper sequence.

Tensile Creep of Epon 828 Laminate

Just because data obtained from a specimen did not agree closely with data taken from an arbitrarily chosen reference standard did not mean that the former value was incorrect. For example, in Table V, there were only three specimens tested. In Table V*a*, specimen 1 was chosen as the standard, primarily because the data extended to 1000 hr, thus allowing the calculation of all the other data. Evidently this was a poor choice because the creep results of specimens 2 and 3 were thrown out quite far—in one case to −17.4 per cent. In Table V*b*, the effect of choosing specimen 2 as a reference standard is shown. Although all the data do not agree within 10 per cent, it was obviously a much better selection.

Tensile Creep—Epon 828 Laminate—Wet

Table VI shows the results of creep on only 4 specimens. Only specimen 2 was out of sequence. Specimen 1 was chosen as the reference standard. The calculated results of specimens 3 and 4 were in excellent agreement with the observed results, all of the data agreeing within 5 per cent.

Tensile Creep—Selectron 5003 Laminate —Wet

Table VII shows the results of testing specimens immersed in water for long periods of time. Twelve specimens were tested. Of these, 3 (specimens 3, 9, and 11) were obviously out of the correct sequence for 0-hr elongation. Specimens 5 to 7 had 0-hr elongations so close that not more than one of the three could be correct. Thus the data on 5 specimens of the 12 were obviously

TABLE I.—VARIATION OF TENSILE MODULUS OF ELASTICITY WITH TEMPERATURE IN GLASS REINFORCED PLASTICS.[a]

Laminate	Temperature		Modulus of Elasticity, psi		K $T(20 + \log t)$ ($t = 10^{-4}$ hr)	Proportional Limit, psi		Short Time Tensile Strength, psi
	deg Fahr	deg Fahr abs	Primary	Secondary		Primary	Secondary	
Plaskon 920[b]	75	535	2.69×10^6	2.53×10^6	8 560	....	23 100	39 100
	80	540	....	....	8 650	....	....	
	200	660	2.50×10^6	2.36	10 550	....	19 200	
	300	760	2.34	2.27	12 150	11 550	20 250	
	400	860	2.25	....	13 780	14 100	....	
	500	960	2.14	....	15 360	8 730	....	
Stypol 16B[b]	75	535	2.64	2.51	8 560	5 880	12 100	34 900
	300	760	2.52	2.26	12 150	7 500	15 100	
	500	960	2.34	....	15 360	6 790	....	
Selectron 5003[b]	75	535	3.04	2.64	8 560	9 100	28 450	53 800
	200	660	2.50	2.34	10 550	10 150	19 800	
	300	760	2.46	1.92	12 150	5 310	26 600	

[a] Source data from *USAF Rep. No. 6172*, May 31, 1950. "Elevated Temperature Properties of Glass Fabric Base Plastic Laminates," Battelle Memorial Inst.
[b] All laminates were fabricated using style 181 glass cloth, 114 finish.

TABLE II.—TENSILE CREEP DATA OF GLASS REINFORCED PLASTIC LAMINATES.[a]

Specimen	Resin	Temperature, deg Fahr	Rupture Time, hr	Stress, psi	K $T(20 + \log t)$	Equivalent Modulus, psi	Observed Creep, %	Calculated Creep, Stress/Equiv. Mod.	Difference between Observed and Calculated Creep, per cent	Remarks
	Plaskon									
A-28	920[b]	80	3.8	30 000	11 200	2.32×10^6	1.25	1.30	+ 4.0	
A-33	920[b]	80	3.8	29 500	11 200	2.32×10^6	1.35	1.27	− 5.9	
A-34	920[b]	80	194.6	29 000	12 380	2.26×10^6	1.20	1.28	+ 6.7	extrap.
D-14	920[b]	80	1077	29 000	12 420	2.25×10^6	1.16	1.29	+11.2	extrap.
A-29	920[b]	200	1.7	28 000	13 350	....	1.54	...	...	off curve
A-27	920[b]	200	23.7	27 500	14 080	....	1.52	...	...	off curve
A-30	920[b]	200	1178	27 000	15 230	....	1.52	...	...	off curve
SATC-10	Stypol 16B	80	552.8	24 000	12 280	2.26×10^6	1.19	1.06	−10.9	
SATC-6	16B	80	1032	21 000	12 420	2.25×10^6	0.924	0.933	+ 0.98	
SEBTC-14	Selectron 5003	80	60.7	39 000	11 750	2.03	2.15	1.94	− 9.8	
SEBTC-17	5003	80	116.6	37 500	11 900	1.99	1.49	1.88	+26.2	
SEBTC-8	5003	80	720	36 000	12 340	....	1.29	...	...	off curve
SEBTC-7	5003	80	955	31 500	12 400	....	1.22	...	...	off curve

[a] Source data from *USAF Rep. No. 6172*, May 31, 1950. "Elevated Temperature Properties of Glass Fabric Base Plastic Laminates," Battelle Memorial Inst.
[b] All laminates were fabricated using style 181 glass cloth, 114 finish.

TABLE III.—DETERMINATION OF EQUIVALENT MODULUS FOR MASTER TENSILE AND FLEXURAL MODULUS CURVES.

	Tensile[a]					Flexural[b]		
	Dry (73 F)		Wet (73 F)		Dry (73 F)	Wet (73 F)		
	Selectron 5003	Epon 828 and CL	Selectron 5003	Epon 828 and CL	Selectron 5003	Epon 828 and CL	Selectron 5003	Epon 828 and CL
Temperature, (T), Fahr abs	533	533	533	533	533	533	533	533
Stress, psi	24 200	40 600	15 850	31 100	33 300	53 400	15 500	37 800
Time, t, 0.1 hr								
Observed creep, per cent	1.044	1.337	0.775	1.022	1.120	2.375	0.573	1.380
Calc. equiv. E, psi	2 320 000	3 035 000	2 045 000	3 041 000	1 983 000	1 495 000	1 800 000	1 825 000
$K = T(20 + \log t)$	10 110	10 110	10 110	10 110	10 110	10 110	10 110	10 110
Time, t, 1 hr.								
Observed creep, per cent	1.073	1.350	0.792	1.040	1.163	2.404	0.598	1.406
Calc. equiv. E, psi	2 260 000	3 005 000	2 001 000	2 990 000	1 910 000	1 480 000	1 725 000	1 791 000
$K = T(20 + \log t)$	10 650	10 650	10 650	10 650	10 650	10 650	10 650	10 650
Time, t, 10 hr								
Observed creep, per cent	1.102	1.372	0.814	1.068	1.222	2.442	0.629	1.450
Calc. equiv. E, psi	2 190 000	2 955 000	1 949 000	2 915 000	1 818 000	1 465 000	1 640 000	1 738 000
$K = T(20 + \log t)$	11 200	11 200	11 200	11 200	11 200	11 200	11 200	11 200
Time, t, 100 hr								
Observed creep, per cent	1.130	...	0.848	1.131	1.305	2.518	0.678	1.518
Calc. equiv. E, psi	2 140 000	...	1 871 000	2 790 000	1 700 000	1 415 000	1 523 000	1 660 000
$K = T(20 + \log t)$	11 700	...	11 700	11 700	11 700	11 700	11 700	11 700
Time, t, 1000 hr								
Observed creep, per cent	1.170	...	0.894	..	1.406	...	0.770	1.645
Calc. equiv. E, psi	2 070 000	...	1 775 000	...	1 576 000	...	1 340 000	1 532 000
$K = T(20 + \log t)$	12 250	...	12 250	...	12 250	...	12 250	12 250
Time, t, 10,000 hr								
Observed creep, per cent	1.206	...	...	...	1.601	...	0.943	...
Calc. equiv. E, psi	2 010 000	...	...	...	1 386 000	...	1 095 000	...
$K = T(20 + \log t)$	12 790	...	...	...	12 790	...	12 790	...

[a] Tensile E = stress/creep.
[b] Flexural $E = SL^3/6dl = 6.66$ (stress)/(creep).

TABLE IV.—DETERMINATION OF CREEP, PER CENT, FROM MASTER TENSILE MODULUS CURVE FOR SELECTRON 5003 LAMINATE.[b]

Specimen	Applied Stress psi[a]	0-hr Elongation, per cent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			10 000 hr			Remarks
			Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
No. 1..	16 100	0.801	0.819	0.695	− 15.2	0.829	0.713	−14.0	0.842	0.735	−12.7	0.868	0.752	−13.5	0.892	0.778	−12.8	0.913	0.801	−11.5	Probably poor specimen
No. 2..	18 200	0.829	0.840	0.784	− 6.7	0.852	0.805	− 5.5	0.874	0.831	− 4.6	0.900	0.850	− 5.6	0.930	0.879	− 5.5	0.962	0.905	− 5.9	
No. 3..	20 200	0.724	0.736	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
No. 4..	22 200	0.815	0.822	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
No. 5..	24 200	1.033	1.044	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Reference standard
No. 6..	26 200	0.977	0.985	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
No. 7..	28 200	1.216	1.240	1.215	− 2.0	1.266	1.250	− 1.3	1.298	1.288	− 0.8	...	...	...	...	...	...	...	...	...	
No. 8..	30 200	1.332	1.347	1.308	− 2.9	1.374	1.341	− 2.4	1.422	1.385	− 2.6	1.478	1.415	− 4.3	...	...	...	...	...	...	
No. 9..	32 300	1.468	1.489	1.393	− 6.5	1.531	1.430	− 7.2	...	...	...	...	...	...	...	...	...	...	...	...	

[a] Ultimate strength, 40 300 psi.
[b] Fabricated with style 181 glass cloth, 114 finish.

TABLE V.—DETERMINATION OF CREEP, PER CENT, FROM MASTER TENSILE MODULUS CURVE FOR EPON 828 LAMINATE.[b]

Specimen	Applied Stress, psi[a]	0-hr Elongation, per cent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			Remarks
			Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
(*a*) Specimen 1 Chosen as Standard																		
No. 1..	37 900	1.096	1.22	...	...	1.133	...	...	1.152	...	...	1.183	...	...	1.261	...	...	Reference standard
No. 2..	40 600	1.320	1.337	1.200	−10.3	1.350	1.213	−10.2	1.372	1.235	−10.0	...	...	...	...	...	...	
No. 3..	43 300	1.490	1.536	1.282	−16.5	1.562	1.290	−17.4	...	...	...	...	...	...	...	...	...	
(*b*) Specimen 2 Chosen as Standard																		
No. 1..	37 900	1.096	1.122	1.215	+ 8.30	1.133	1.261	+11.3	1.152	1.285	+11.5	1.183	...	...	1.261	...	...	100-hr creep cannot be calculated, no data
No. 2..	40 600	1.320	1.337	...	...	1.350	...	...	1.372	...	...	...	...	...	...	...	...	Reference standard
No. 3..	43 300	1.490	1.536	1.428	− 0.52	1.562	1.440	− 7.80	...	...	...	...	...	...	...	...	...	

[a] Ultimate strength, 54 100 psi.
[b] Fabricated with style 181 glass cloth, Volan A finish, resin cured with curing agent CL.

TABLE VI.—DETERMINATION OF CREEP, PER CENT, FROM MASTER TENSILE MODULUS CURVE FOR EPON 828 LAMINATE.[b]
Tested at 73 F in Water.

Specimen	Applied Stress, psi[a]	Per cent of Maximum	0-hr Elongation, percent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			Remarks
				Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
No. 1..	31 100	60	0.988	1.022	...	...	1.040	...	...	1.068	...	...	1.131	...	...	...	...	...	Reference standard
No. 2..	33 700	65	0.844	0.901	...	...	0.920	...	...	0.950	...	...	1.009	...	...	1.104	...	...	Out of sequence
No. 3..	36 400	70	1.140	1.175	1.192	+1.45	1.192	1.218	+2.18	1.250	1.250	0	1.365	1.305	−4.39	...	...	...	
No. 4..	38 900	75	1.260	1.273	1.278	+0.39	1.310	1.301	−0.69	...	...	...	...	...	...	...	...	...	

[a] Ultimate strength, 51 910 psi.
[b] Fabricated with style 181 glass cloth, Volan A finish, resin cured with curing agent CL.

TABLE VII.—DETERMINATION OF CREEP, PER CENT, FROM MASTER TENSILE MODULUS CURVE FOR SELECTRON 5003 LAMINATE.[b]
Tested at 73 F in Water.

Specimen	Applied Stress, psi[a]	0-hr Elongation, Percent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			10 000 hr			Remarks
			Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
No. 1	9 220	0.341	0.352	0.451	+27.1	0.360	0.460	+28.5	0.370	0.473	+27.8	0.385	0.493	+28.1	0.415	0.519	+25.1	...	...	...	Cannot calculate 10 000 hr because No. 4, does not have data
No. 2	11 900	0.443	0.451	0.582	+28.0	0.464	0.594	+28.0	0.480	0.611	+27.3	0.504	0.636	+26.2	0.537	0.670	+24.7	0.573	...	...	
No. 3	13 870	0.426	0.437	...	...	0.448	...	...	0.464	...	...	0.486	...	...	0.522	...	...	0.646	...	...	Obviously poor specimen
No. 4	15 850	0.760	0.775	...	...	0.792	...	...	0.814	...	...	0.848	...	...	0.894	...	...	...	...	...	Reference standard
No. 5	17 850	0.860	0.871	0.873	+ 2.29	0.885	0.891	+ 6.8	0.908	0.916	+ 8.82	0.951	0.954	+ 3.2	...	...	...	...	...	...	0-hr elongations too close for more than one or two to be close to correct
No. 6	19 850	0.865	0.876	0.971	+10.9	0.890	0.990	+11.2	0.912	1.019	+11.7	0.948	1.060	+11.8							
No. 7	21 800	0.896	0.916	1.066	+16.4	0.940	1.089	+14.9	0.962	1.119	+16.4	1.010	1.165	+15.4							
No. 8	23 800	1.090	1.105	1.163	+ 5.25	1.135	1.189	+ 4.76	...	...	...	...	...	...	...	...	...	...	...	...	
No. 9	25 800	0.980	0.996	...	...	1.015	...	...	1.051	...	...	...	...	...	...	...	...	...	...	...	
No. 10	27 800	1.210	1.225	1.358	+10.9	1.262	1.388	+ 9.97	...	...	...	...	...	...	...	...	...	...	...	...	Specimen failed before data were obtained
No. 11	29 750	1.117	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
No. 12	31 700	1.451	1.476	1.549	+ 4.95	...	...	...	...	...	...	...	..	...	...	...	...	...	...	...	

[a] Ultimate strength, 40 000 psi.
[b] Fabricated with style 181 glass cloth, 136 finish.

TABLE VIII.—DETERMINATION OF CREEP, PER CENT, FROM MASTER FLEXURAL MODULUS CURVE FOR SELECTRON 5003 LAMINATE.[b]

Specimen	Applied Stress, psi[a]	0-hr Elongation, per cent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			10 000 hr			Remarks
			Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
No. 1	22 200	0.690	0.705	0.746	+ 5.82	0.729	0.798	+9.47	0.761	0.815	+ 7.10	0.823	0.870	+5.72	0.904	0.937	+3.66	0.997	1.066	+6.92	
No. 2	25 000	0.843	0.858	0.841	− 1.98	0.883	0.898	+1.70	0.913	0.917	+ 4.38	0.964	0.980	+1.66	1.048	1.055	+0.67	1.178	1.202	+2.04	
No. 3	27 700	0.968	0.988	0.931	− 5.78	1.018	0.995	−2.26	1.058	1.015	− 4.07	1.148	1.085	−5.49	1.278	1.170	−8.45	1.468	1.331	−9.34	
No. 4	29 200	0.971	0.997	0.983	− 1.41	1.026	1.048	+2.14	1.075	1.070	− 0.46	1.141	1.145	+0.28	1.257	1.233	−1.91	1.446	1.405	−2.84	
No. 5	30 600	1.076	1.091	1.028	− 5.77	1.112	1.099	−1.16	1.168	1.121	− 2.80	1.264	1.198	−5.22	1.426	1.291	−9.47	1.626	1.471	−9.53	Reference standard
No. 6	33 300	1.111	1.120	...	...	1.163	...	...	1.222	...	...	1.305	...	...	1.406	...	...	1.601	...	...	
No. 7	36 100	1.244	1.264	1.213	− 4.04	1.306	1.295	−0.84	1.371	1.323	− 3.50	1.491	1.415	−5.09	1.676	1.525	−9.01	...	...	...	
No. 8	38 200	1.440	1.468	1.284	−12.6	1.514	1.371	−9.45	1.614	1.400	−13.3	...	...	...	...	..	...	...	...	...	
No. 9	41 600	1.474	1.506	1.390	− 7.70	1.557	1.494	−4.04	1.659	1.525	− 8.08	...	...	...	...	...	...	...	...	...	
No. 10	44 400	1.630	1.639	1.492	− 9.85	1.687	1.593	−5.57	...	...	...	...	...	...	...	...	...	...	...	...	

[a] Ultimate strength, 55 500 psi.
[b] Fabricated with style 181 glass cloth, 136 finish.

TABLE IX.—DETERMINATION OF CREEP, PER CENT, FROM MASTER FLEXURAL MODULUS CURVE FOR EPON 828 LAMINATE.[b]

Specimen	Applied Stress, psi[a]	0-hr Elongation, per cent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			Remarks
			Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
No. 1	46 300	2.090	2.125	2.380	+12.0	2.163	2.080	− 3.83	2.211	2.101	−4.97	2.278	2.180	−4.3	2.375	...	...	
No. 2	49 900	2.100	2.140	2.225	+ 3.97	2.165	2.245	+ 3.69	2.206	2.270	+2.90	...	...	...	...	...	...	Test discontinued, premature failure
No. 3	53 400	2.330	2.375	...	...	2.404	...	...	2.442	...	...	2.518	..	...	...	...	..	Reference standard
No. 4	58 600	2.340	2.430	2.615	+ 7.71	2.490	2.741	+10.1	...	...	...	..	...	...	...	...	...	

[a] Ultimate strength, 71 220 psi.
[b] Fabricated with style 181 glass cloth, Volan A finish, resin cured with curing agent CL.

TABLE X.—DETERMINATION OF CREEP, PER CENT FROM MASTER FLEXURAL MODULUS CURVE FOR SELECTRON 5003 LAMINATE.[b]

Tested at 73 F in water.

Specimen	Applied Stress, psi[a]	0-hr Elongation, per cent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			10 000 hr			Remarks
			Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	
No. 1	15 500	0.553	0.573	...	...	0.598	...	...	0.629	...	...	0.678	...	...	0.770	..		0 943			Reference standard too close to No. 1 may be faulty
No. 2	18 100	0.593	0.610	0.670	+ 9.83	0.633	0.699	+10.44	0.663	0.735	+10.9	0.707	0.793	+12.1	0 790	0 900	+13 9	0 925	1.090	+17.8	
No. 3	20 600	0.908	0.931	0.762	−18.2	0.958	0.795	−16.6	0.998	0.837	−16.1	1.059	0.903	−14.8	1.172	1.024	−13.5	...	...	...	Either specimen 3 or 4 is faulty
No. 4	23 200	0.878	0.903	0.858	− 4.99	0.930	0.895	− 3.76	0.968	0.943	− 2.6	1.018	1.015	− 0.3	1.108	1.152	+ 4.0	...	...	...	
No. 5	25 800	1.011	1.040	0.991	− 4.71	1.086	0.955	−12.1	1.155	1.048	− 9.27	1.258	1.130	−10.2	...	...	...	...	...	...	
No. 6	28 400	1.228	1.248	1.050	−15.9	1.286	1.095	−14.9	1.368	1.152	−15.8	1.483	1.242	−16.2							One or more of specimens 6 to 8 are faulty
No. 7	31 100	1.208	1.234	1.150	− 6.81	1.282	1.200	− 6.4	1.391	1.263	− 9.20	...	...	...	...	...	...	...	...	...	
No. 8	33 600	1.154	1.185	1.241	+ 4.73	1.239	1.296	+ 4.40	1.347	1.365	+ 1.34	...	...	...	...	...	...	...	...	...	
No. 9	36 200	1.342	1.374	1.339	+ 2.55	1.432	1.396	− 2.51	...	...	...	...	...	...	...	...	...	...	...	...	
No. 10	38 800	1.454	1.495	1.435	− 4.02	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Specimen may be faulty since jump in elongation over No. 10 is too large
No. 11	41 200	1.806	1.922	1.523	+20.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	

[a] Ultimate strength 51 700 psi.
[b] Fabricated with style 181 glass cloth, 136 finish.

TABLE XI.—DETERMINATION OF CREEP, PER CENT FROM MASTER FLEXURAL MODULUS CURVE FOR EPON 828 LAMINATE.[b]

Tested at 73 F in water.

Specimen	Applied stress, psi[a]	Per cent of Maximum	0-hr Elongation, per cent	0.1 hr			1 hr			10 hr			100 hr			1000 hr			10 000 hr			Remarks
				Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Difference	Observed	Calculated	Calculence	Observed	Calculated	Difference	
No. 1	37 800	55	1.340	1.380	...	...	1.406	...	...	1.450	...	...	1.518	...	...	1.645	...	...	...	...	...	Reference standard
No. 2	41 250	60	1.590	1.635	1.508	−7.77	1.667	1.535	−7.92	1.716	1.581	−7.87	1.795	1.658	−7.64	1.945	1.795	−7.72	...	...	...	
No. 3	44 650	65	1.670	1.728	1.630	−5.67	1.760	1.660	−5.69	1.825	1.714	−6.08	...	...	...	...	...	...	...	...	...	
No. 4	48 100	70	1.790	1.843	1.755	−4.78	1.879	1.788	−4.84	1.926	1.843	−4.31	...	...	...	...	...	...	...	...	...	
No. 5	51 550	75	1.880	1.956	1.884	−3.68	2.034	1.920	−5.60	2.122	1.979	−6.73	...	...	...	...	...	...	...	...	...	
No. 6	54 950	80	2.042	2.115	2.005	−5.20	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	

[a] Ultimate strength 68 780 psi.
[b] Fabricated with style 181 glass cloth, Volan A finish, resin cured with curing agent CL.

incorrect. With specimen 4 chosen as the standard, this left six specimens to be evaluated. Of the six remaining all gave fairly good results except specimens 1 and 2, which were off by very large percentages.

Flexural Creep—Selectron 5003 Laminate

Table VIII shows the results of the determination of 10 specimens under continual flexural stress, 5 of them up to 10,000 hr. The test appears to have been well conducted and the specimens uniform. All of the 0-hr elongations are in their correct order, although some of them are close. Of the 41 determinations, 39 of the calculated results agreed with the observed results within 10 per cent. Two observations were 12.6 and 13.3 per cent, both for specimen 8. All of the 10,000-hr calculations were within 10 per cent of the observed data.

Flexural Creep—Epon 828 Laminate

Table IX shows only 4 specimens with data disclosed. Specimen 3 was chosen as a reference standard with which to set up the master modulus curve. Of the 10 determinations, 8 of the calculations agreed with the observation within 10 per cent. Of the two which were over 10 per cent, one was 12 and the other 10.1 per cent. The 12 per cent agreement was in the 1-hr determination for specimen 1. Subsequent agreements for the 1-hr test were 3.8 per cent; for the 10-hr test, −5.0 per cent; and for the 100-hr test, −4.3 per cent.

Flexural Creep—Selectron 5003 Laminate —Wet

Table X shows 11 specimens tested. Specimen 1 was taken as a reference standard. Specimen 2 had a 0-hr deflection very close to that of 1 so that although it was in the correct sequence it could be faulty. Either specimen 3 or 4 is faulty from the data. One or more of specimens 6 to 8 are defective from the results. Specimen 11 takes a disproportionately large jump over specimen 10 for its 0-hr elongation. Thus, out of 11 specimens, data on four cannot be used. Of the remaining specimens the results indicated good agreement—in most cases within 10 per cent.

Flexural Creep—Epon 828 Laminate—Wet

Table II indicated that the test was a good one with no poor specimens. The 0-hr elongations were all in correct sequence. Six specimens were tested with specimen 1 being used as a standard. Of the 15 measurements, all the calculated results agreed with the observed results within 10 per cent.

In the case of the flexural tests, an assumption was made in the procedure that all the specimens were 0.1 in. thick. A variation of 10 per cent in the thickness of a specimen could change the creep results by 10 per cent. This might explain some of the poor results which were obtained which could not be explained in any other manner. In addition, the data represent properties of single specimens and not an average.

The selection of a specimen as a reference was not done arbitrarily. One of the main requirements was that the 0-hr elongation appear in the proper sequence. Secondly, the available data should go out as far as possible. If the latter was not the case for example, where data only extended to 1000 hr, creep at other stress levels extending to 10,000 hr could not be determined without extrapolation of the master modulus curve. This was not attempted.

The assumption was made that the stress-strain curves were straight lines. This allowed calculation of creep at all stress levels. That this is not exactly the case is seen in Table I where primary and secondary moduli differ in some cases more than 10 per cent. A tendency for this difference to increase at high temperatures is also noted. Selection of a standard reference at a mean stress probably would minimize such errors.

It is reiterated that the method of calculating creep at one creep level in order to obtain creep at other creep levels was resorted to here to obtain data to prove out the theory and is recommended only in the absence of modulus data at high temperatures.

It is also observed that a complete curve need not be drawn if only isolated data are required. If the creep at 10,000 hr at 73 F is required, then since

$$T_1(20 + \log t_1) = T_2(20 + \log t_2)$$

$$(460 + 73)(20 + \log 10{,}000) = T_2(20 + \log 10^{-4})$$

T_2 = 798 deg Fahr absolute = 338 F only the modulus at 338 F need be determined.

Conclusions

Creep properties of glass-reinforced plastics may be calculated from modulus of elasticity data at high temperatures using the concept of a steady load static time equivalent and the parameter $T(20 + \log t)$ (T = absolute temperature and t = time).

Tensile and flexural creep were capable of being determined with comparable accuracy for both polyester and epoxy laminates, wet and dry.

The results were accurate to well within 10 per cent for periods of time from 0.1 to 10,000 hr (extent of test).

If modulus data are not available, creep data at one stress level will enable creep data at other stress levels to be calculated with equal accuracy.

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A Fixture for Compression Testing of Sheet Materials at Elevated Temperatures

By B. L. MOLANDER, C. R. WALDRON, and J. C. NEWLAND

THE BUCKLING tendency of sheet materials under compression has posed a problem to metallurgical engineers in many laboratories. Solution requires a fixture that will provide complete stabilization of the test specimen, and yet allow it the freedom necessary to avoid inaccurate data resulting from longitudinal or lateral restraint. Fixtures designed to accomplish this objective have taken several forms, with little agreement having been reached as to which is the most acceptable. The situation is now further complicated by the need for mechanical property data of materials at elevated temperatures. With tests being run at 1000 F and higher, rusting and scaling of fixtures, as well as deformation of fixture parts, become sources of trouble and error.

A device that reduces these high-temperature factors to a minimum and yet inhibits buckling has been developed by North American Aviation engineers. The fixture utilizes leaf-spring guides which move easily with compressive deformation of the test specimen but offer high resistance to lateral deflection.

Other designs in current use which provide similar support include solid guides, grooved guides, and rotating steel balls as guides. Advantages of the North American Aviation design are the elimination of maintenance trouble and of unreliable data caused by friction at high temperatures. Such friction may result in the specimen's being subjected to scaling, galling, and seizing.

Development

Development of the fixture has taken approximately three years and has involved four different designs prior to the evolution of its final two forms. In principle, the jig is similar to one devised for room-temperature testing by the Forest Products Laboratory of the U. S. Department of Agriculture. Continued refinements at North American Aviation however, have led to the jig's applicability to testing at elevated temperatures. The two forms, one for metallic materials and the other for

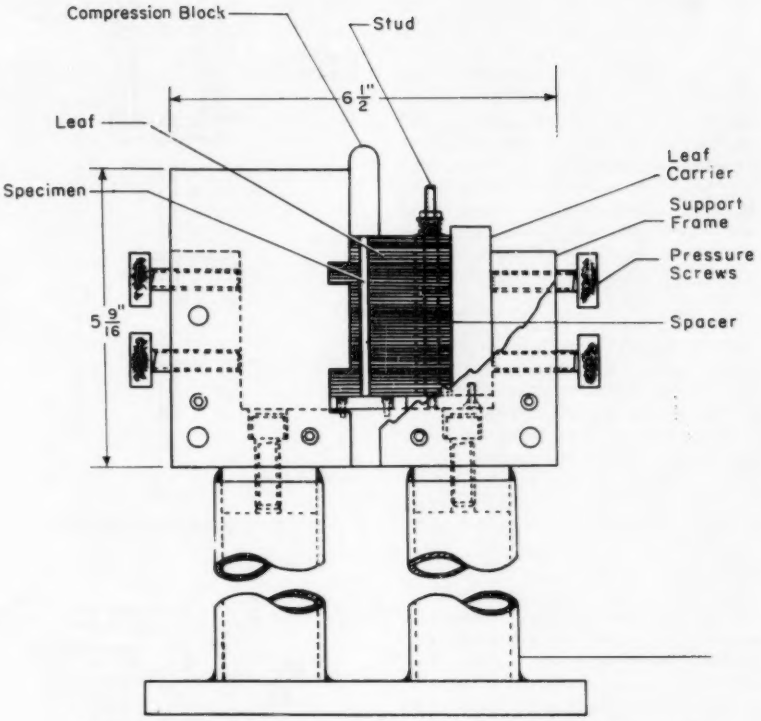

Fig. 1.—Laminated plastic compression fixture with one cover removed.

B. L. MOLANDER, metallurgical group leader, Materials Research Section, North American Aviation's Missile Development Div., Downey, Calif., has been associated with North American for the past ten years, where he has worked to develop improved methods of testing and fabricating advanced materials.

C. R. WALDRON, supervisor, Physical and Mechanical Testing Unit, Materials Research Section, a metallurgist and test engineer in the aircraft industry and in atomic power development, has conducted materials research at North American for the past five years.

J. C. NEWLAND, senior research engineer, Materials Research Section, has been engaged in materials research work since 1950, and has dealt primarily with the production of temperature extremes for determining the physical and mechanical properties of missile materials.

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laminated plastics, both utilize the leaf-spring assembly for lateral support. Differences involve the manner in which loads are applied to the two types of specimens.

When the fixture is used with plastics, end-failure tendencies of these materials require that the load be transmitted through clamps. These clamps reduce the possibility of damaging the ends of specimens by use of a $\frac{1}{16}$-in. strip of asbestos which is hand-tightened against the rough side of the laminate by a setscrew. The cushioning of the asbestos pad equalizes the pressure across the 1-in. end of the test specimen and minimizes the stress-raising condition normally existing along the edges of the clamps. Centering of the load is achieved by machining the clamps to close tolerances and by the small roller seated in the upper clamp's V-shape trough.

In order to allow for slight misalignment of the specimen in the 1- by 3-in. plane, a space of from $\frac{3}{32}$ to $\frac{1}{8}$ in. is maintained between the outermost leaves and the two end clamps.

When testing is conducted on metal specimens, support is provided in the manner shown by Fig. 1. Axiality of load is accomplished by careful centering of load application and close-tolerance machining of test specimens. Tolerances at the Materials Research Laboratory of the Missile Development Division require that metal specimen ends be square and parallel to within 0.0005 in., that the sides be square to within $\frac{1}{4}$ deg, and that the surface finish of ends be ground to a maximum of 32 microinches rms. Still, a saving in grinding and polishing time is realized by the fact that faces may remain in the "as received" condition because neither rolling nor sliding is encountered. Centering of the applied load is accomplished by an accurately centered block, which may be seen in Fig. 1.

Both models of the test fixture use the extensometer shown in Fig. 2. In this design, each of the two pairs of knife edges is held against the specimen by a setscrew that pinches the arms to which the knife edges are fixed. The arrangement requires that each setscrew pass freely through at least one arm of the unaffected arm assembly. The slots provided for this free passage are of sufficient size to allow ample vertical movement of the arms. The only guidance effected between the upper and lower knife edge assemblies is by the microformer and the specimen itself. Tests using a deliberately misaligned load have shown that this design will average the misalignment when the difference in strain between the two edges of the specimen does not exceed 0.0005 in. per in. Assuming normal care is taken in centering the load, the accommodation is considered adequate.

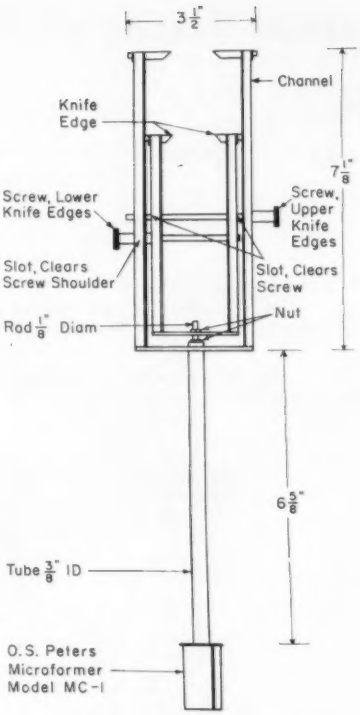

Fig. 2.—Extensometer assembly.

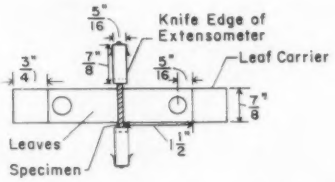

Fig. 3.—Simplified top view of compression fixture.

In order to obtain an accurate load-deformation curve commencing with the first application of load, a $\frac{1}{32}$-in. thick U-shaped shim is inserted around the rod and above the lower nut of the extensometer before it is set to the specimen. After the knife edges have been firmly set, the shim is removed. This procedure prevents the upper knife edge assembly from supporting the lower knife edge assembly before testing and thus eliminates error in the strain measurement when load is first applied.

The 2-in. gage length provides a distance of $\frac{1}{2}$ in. from each end of the 3-in. specimen for further absorption of distortion created by loading effects at the ends of the specimen.

Specimen thickness is limited by the load-carrying ability of the support frame section spanning the support columns. In this laboratory maximum loads have been set at 25,000 lb for room temperature, 20,000 lb for 500 F, 15,000 lb for 700 F, and 12,000 lb for 900 F. A minimum specimen thickness has been set at approximately 0.040 in., although material as thin as 0.024 in. has been tested successfully.

Specimen temperature is determined by two thermocouples of 28-gage wire placed on the faces of the test specimen between the supporting leaves at each end of the 2-in. gage length. This placement was established after careful testing with a dummy specimen equipped with thermocouples brazed into its center. The dummy was checked throughout the range extending from room temperature to 1000 F.

Accuracy

In precise compression testing of sheet materials at room temperature, with use of a 2-in. gage length and a calibrated extensometer system, approximately ± 5 per cent variation of moduli has been observed. This variation is attributed to such additive factors as temperature changes, nonuniformity of materials tested, and to error in measurements of gage length, specimen dimensions, strain and load.

As a means for comparison results of tests conducted with round bars and sheet material machined from the same stock are given in Table I. The tests were run at room temperature with both 2024–T3 aluminum alloy and AISI 4130 steel alloy. Sheet specimen face size was 1 by 3 in. for both types, while the average thickness of the aluminum alloy was 0.080 in. and of the steel alloy was 0.088 in. Bar specimens were machined to a 1-in. diam. and a 3-in. length, thus allowing for a similar 2-in. gage length. It will be seen that the resultant modulus for the bar and sheet of each material was within 0.2 $\times 10^6$ psi.

Another factor which was considered with relation to accuracy was the effect, if any, of leaf-spring tightness on test readings. Results of eight tests run to determine this effect are shown in Table II. Four tests were made with leaf springs held against the specimens by turning the adjusting screws to maximum handtightness, and four tests were made with the adjusting screws turned to hold the leaf springs but snugly against the specimens. The results disclosed that differences were insignificant and that, therefore, no error of consequence is introduced by varying the pressure of the leaf springs against the test specimens so long as direct contact is made.

TABLE I.—COMPRESSION TESTING OF COLUMNS AND SIMULATED SHEET MACHINED FROM SAME STOCK.[a]

Specimen Material and Shape	Nominal Dimensions, in.	Number of Tests	Yield Stress, psi		Modulus, psi	
			Average	Range	Average	Range
2024–T3 Aluminum alloy column	1 in. diam, 3 in. length	6	45,700	2600	10.8×10^6	0.9×10^6
2024-T3 Aluminum alloy sheet	$0.080 \times 1 \times 3$	6	48,200	1900	11.0	0.9
AISL 4130 Steel alloy column	1 in. diam, 3 in. length	6	118,300	1400	30.1	1.4
AISI 4130 Steel alloy sheet	$0.088 \times 1 \times 3$	6	119,500	1600	30.3	2.8

[a] Grain direction was longitudinal. Ambient temperature conditions prevailed.

TABLE II.—COMPRESSION TEST RESULTS OBTAINED WITH VARIED LATERAL SUPPORT PRESSURES ON TITANIUM ALLOY SHEET RC-A110AT.[a]

Stabilizer Pressure	Number of Tests	Yield Stress, psi		Modulus, psi $\times 10^{-6}$	
		Average	Range	Average	Range
Tight	4	129,400	3600	17.0	0.8
Snug	4	129,400	3200	17.1	0.9

[a] Specimen dimensions were 1 by 3 by 0.130 in. Grain direction was longitudinal. Ambient temperature conditions prevailed.

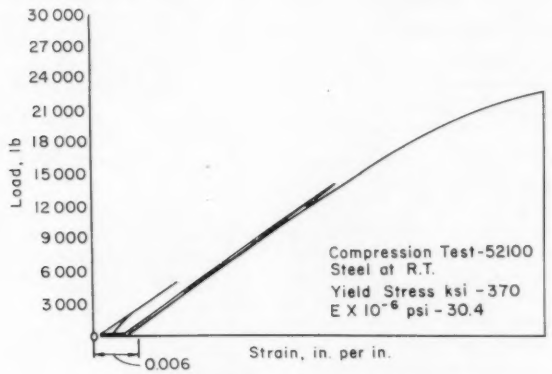

Fig. 4.—Data reproduction with one specimen.

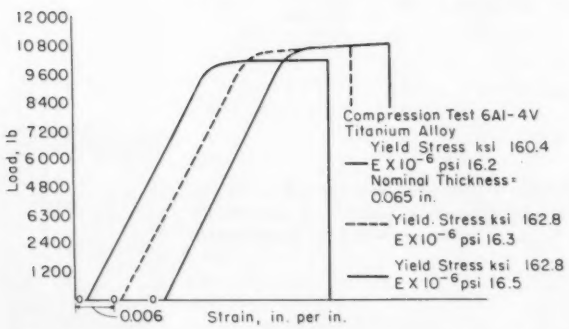

Fig. 5.—Data reproduction with three specimens at room temperature.

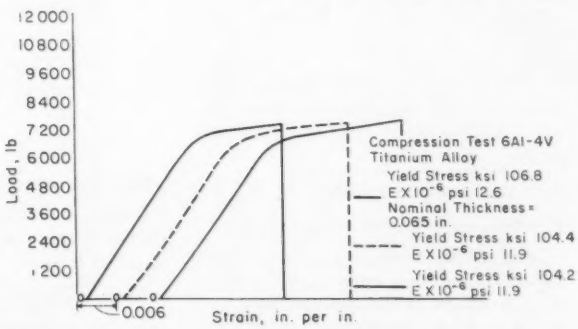

Fig. 6.—Data reproduction with three specimens at 900 F

Reproducibility is also to be considered. Figure 4 illustrates how well the load-deformation curve is reproduced by repeated loading of the same specimen. Figures 5 and 6 illustrate reproduction of data with different specimens of the same stock, Fig. 5 when conducted at room temperature, Fig. 6 when at 900 F.

It may be briefly noted here that this fixture is used for low-temperature compression testing as well, the only variation being that it is placed upside down in order to position the microformer above the cold box and thus remove the possibility of malfunction from the excess of cold air beneath the box. Generally speaking, the use of this compression-testing fixture in conjunction with a circulating air furnace has proven satisfactory not only from the viewpoint of providing accurate data but also because of the speed with which tests can be set up. Within the laboratory, an average of six tests are conducted per hour under ambient conditions and three tests per hour at 1000 F.

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A Review of Sonic Methods for the Determination of Mechanical Properties of Solid Materials

By C. E. KESLER and T. S. CHANG

THE BASIC mathematical expressions for wave propagation were published by Rayleigh (1)[1] in 1877, yet intensive development of sonic testing methods did not begin until about 1937. Sonic testing methods have a major advantage over most static methods; they are nondestructive and, consequently, may be used for inspection of finished products or to determine certain properties of a specimen which is to be subjected to other tests and to allow continued measurements of these properties while the specimen is undergoing other tests. As a result, several sonic testing methods have been developed. In general they may be classified as shown in Table I. It is the purpose of this paper to discuss these various methods and to give the main advantages and disadvantages of each.

The mechanical properties most often determined by sonic testing are the modulus of elasticity in compression, tension and shear, from which Poisson's ratio can be computed. The modulus of elasticity obtained from a sonic test may not be the same as that from a static test; this is particularly true of those materials which have practically no straight-line portion of the stress-strain curve. In a sonic test, since the deformations are very small, the modulus of elasticity so determined may be considered as the initial tangent modulus, whereas in a static test the strains are comparatively large and the modulus is an average. In some methods, a measure of the viscosity of the material may be determined and expressed as damping capacity or as logarithmic decrement.

Resonant Frequency Methods

Equations for Mechanical Properties

Most of the early workers used the resonant frequency method with vibrations produced in the test specimen by mechanical or electronically controlled devices. Often the frequency was adjusted until resonance was obtained as shown by the criterion of maximum amplitude. A preferred definition for resonant frequency is that at which the displacement of the specimen is 90 deg out of phase with the driving force, that is, f_n rather than f_0 in Fig. 1. If the specimen is struck a single hammer blow it will be excited as its damped natural frequency which for small damping is essentially the same as the resonant frequency. The damped natural frequency is simply that at which the specimen will vibrate freely after it is started. It is slightly greater than the frequency for maximum amplitude when the specimen is under forced, damped vibration.

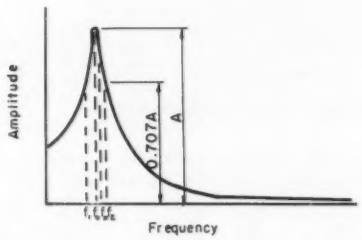

Fig. 1.—Typical damped amplitude-frequency curve.

TABLE I.—CLASSIFICATION OF SONIC TESTING EQUIPMENT.

A.	Resonant frequency type:
	1. Continuous vibration at constant amplitude
	2. Decaying amplitude
B.	Wave velocity type:
	1. Pulse velocity
	a. Soniscope
	b. Interval timer
	2. Standing wave velocity

To obtain the dynamic modulus of elasticity by sonic methods, it is necessary only to determine the resonant frequency of the specimen. The dynamic modulus can then be computed from the equation:

$$E_d = Cwf^2{}_n \quad \ldots\ldots\ldots\ldots (1)$$

where:

E_d = dynamic modulus of elasticity in flexure,
f_n = resonant frequency in flexure,
w = weight of specimen, and
C = a factor which depends upon the shape and size of the specimen, the mode of vibration, and Poisson's ratio.

Pickett (2) has presented a thorough discussion of the factor C and equations and graphs from which C may be determined.

A dynamic modulus of elasticity for shear may be determined using torsional vibration. The shear modulus can then be computed from the following equation:

$$G_d = Dw(f'_n)^2 \quad \ldots\ldots\ldots\ldots (2)$$

where:

G_d = dynamic modulus of elasticity in shear,

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

CLYDE E. KESLER, professor of theoretical and applied mechanics, University of Illinois, has been engaged in research on concrete for the past ten years and has been concerned with sonic properties for the past five years.

TIEN S. CHANG, assistant professor of theoretical and applied mechanics, University of Illinois, has been engaged in research concerning sonic properties of concrete for the past four years.

F'_n = resonant frequency in torsion, and
D = a factor depending on the dimensions of the specimen and the mode of vibration.

Pickett's paper also includes a discussion of the various factors involved in this equation.

If the dynamic modulus of elasticity in shear and in flexure are known, then Poisson's ratio, u, can be computed by the following equation:

$$\mu = (E_d/2G_d) - 1 \quad \text{.....(3)}$$

This equation is good only for isotropic materials and is not applicable to aeolotropic materials such as wood and certain types of stone.

In addition to torsional and flexural vibrations, longitudinal vibrations may be used, and the dynamic modulus of elasticity can then be computed from the equation:

$$E_d = 4l^2 \rho f''^2_n / i^2 \quad \text{.....(4)}$$

where:

E_d = dynamic modulus of elasticity in compression,
l = length,
ρ = mass per unit volume,
f''_n = resonant longitudinal frequency, and
i = an integer depending on the frequency being fundamental or a higher harmonic.

Although Eq. 1 contains a correction for lateral inertia, no such correction is included in Eq. 4 because, for the size of specimens commonly used, the error in Eq. 4 will be small. Nevertheless, if a specimen radically different in dimensions is used, the proper correction should be estimated and applied.

Another factor of some importance is the viscosity or damping of a material, which may be expressed as damping factor or logarithmic decrement.

The damping factor, Q, is given by the following equation provided the damping is small:

$$Q = 2\pi W/\Delta W \quad \text{.....(5)}$$

where:

W = total energy of vibration per unit volume per cycle, and
ΔW = damping capacity—the part of energy per unit volume per cycle used to overcome the internal friction.

This equation has been used by Obert and Duvall (3) in their tests of concrete.

[2] Equations 6 and 7 are based on the differential equation of the form $A\ddot{x} + \dot{x}B + Cx = F(t)$, which describes the behavior of speciemns having only one resonant frequency.

[3] 1955 Book of ASTM Standards, Part 3, p. 1355.

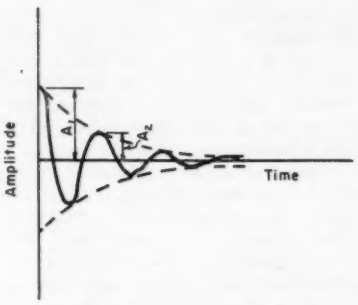

Fig. 2.—Damped free vibration.

The damping factor can be determined from the shape of the response curve, Fig. 1, by using the equation:

$$Q = f_n/(f_2 - f_1) \quad \text{.....(6)}^2$$

where:

f_n = resonant frequency, and
f_1, f_2 = frequencies on either side of resonance at which the amplitude of vibration is 0.707 of the maximum.

The frequencies f_1 and f_2 are located at points on the resonance curve where the amplitude is 0.707 of the maximum for convenience since this allows the general equation to be reduced to the simple form indicated.

The logarithmic decrement is defined by the equation:

$$\delta = ln\,(A_1/A_2) \quad \text{.....(7)}^2$$

where A_1 and A_2 are amplitudes of successive vibrations as indicated in Fig. 2.

The damping factor, Q, and the logarithmic decrement, δ, are related by the equation:

$$Q = \pi/\delta \quad \text{.....(8)}$$

Consequently the logarithmic decrement may be computed from the shape of the resonance curve (Fig. 1) by the following equation:

$$\delta = \pi(f_2 - f_1)/f_n \quad \text{.....(9)}$$

Knowing the resonant frequencies, the above equations enable one to compute the moduli of elasticity and Poisson's ratio. To permit an estimate of the damping in the material it is necessary to determine frequencies at two other locations.

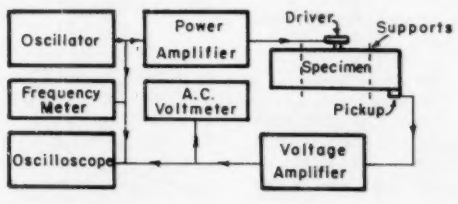

Fig. 3.—Typical resonant frequency apparatus.

Constant Amplitude Sonic Equipment

One type of resonant frequency equipment often used is that shown in Fig. 3. It produces a continuous vibration of constant amplitude and controllable frequency. This apparatus is that included in the ASTM Tentative Method of Test for Fundamental Transverse and Torsional Frequencies of Concrete Specimens (C 215 - 52 T).[3] The essential parts are the oscillator, driver, pickup and an oscilloscope or a.c. voltmeter. Other equipment such as amplifiers and frequency indicators and the inclusion of both an oscilloscope and voltmeter increase the ease of operation of the equipment and test accuracy.

In operation, the oscillator excites the driver, which in turn forces the specimen to vibrate. For free-free vibration, the specimen is supported at the nodal points which, for transverse vibration, are at a distance 0.224 l from the ends of the specimen for the fundamental mode of vibration, l being the length of the specimen. The motion of the specimen excites the pickup whose output may be evaluated with the voltmeter or oscilloscope. The voltmeter will afford the most accurate evaluation of the strength of the signal from the pickup provided the contamination is low. An oscilloscope, here, has an advantage in that it will show any contamination and in addition Lissajous figures will show phase angle relationships and indicate the mode of vibration. The frequency may be read directly from an accurately calibrated oscillator with little error. However, determination of either damping factor or logarithmic decrement requires a much more accurate frequency measurement. This is because the term $(f_2 - f_1)$ in Eqs. 6 and 9 is extremely small compared to the magnitudes of f_1 and f_2. A frequency counter provides a good means of accurate frequency measurement.

This type of equipment may be used to determine the resonant frequencies for torsion and longitudinal vibration by properly upporting and driving the specimen. In general, the same infor-

mation obtained from transverse vibrations may be obtained from longitudinal vibrations of the specimen.

Drivers

If the resonant frequency is in the sonic range at least four methods of exciting the specimen into vibration may be used: 1 mechanical, 2 piezoelectric, 3 electrostatic, and 4 electrodynamic.

The mechanical method most used is some form of hammer; however, this cannot supply a constant amplitude of vibration. It will be discussed later.

In the piezoelectric method, an appropriately cut quartz (or other) crystal is cemented to the specimen. The crystal produces the driving force by changing dimensions in response to an electric signal. If the characteristics of the crystal are known, the dynamic modulus of elasticity can be computed. Tykociner and Woodruff (**4**) used this method in their study of quartz bars and Balamuth (**5**) used it in his study of rock salt.

In the electrostatic method, the oscillator voltage is applied to a condenser, the specimen carrying one plate with the other plate rigidly fixed close to the same end of the specimen. Ide (**6**), Barcroft and Jacobs (**7**), and Kirby (**8**) have used this procedure for vibrating specimens.

In the electrodynamic method, a driving force is produced electromagnetically on one end of the specimen, while at the other end the vibrations are converted into electric magnitudes by an electromagnetic detector. If the specimen is non-magnetic it is necessary to glue ferromagnetic poles to its ends. In a variation of this method, eddy currents have been employed as driver and detecting means. Thomson (**9**) was able to use both a magnetic driver and magnetic pickup in his test on concrete.

A common electrodynamic method uses a modified moving-coil loud speaker, with the voice coil coupled to the specimen either directly or through an air column. Long and Kurtz (**10**) and many others have used this type of driver.

Considerable driving force can be obtained from the mechanical and electrodynamic methods; only a small force can be obtained from the piezoelectric and even less from the electrostatic. The driver damping would be least for the electrostatic and piezoelectric methods and probably greatest for the electrodynamic method.

Pickups

In general, any of the four principles just mentioned for exciting the specimen may be used to detect the vibration except the "hammer" mentioned in the mechanical method. There are mechanical pickups such as Rayleigh disk and optical detectors. The pickup need not be the same type as the driver. Mitchell (**11**) used a speaker-type driver and a phonograph-type crystal pickup for tests on various rock cores.

Depending on the pickup used, its response may indicate displacement, velocity, or acceleration. Regardless of which quantity is measured there will be no difficulty in determining the resonance frequency. Kesler and Higuchi (**12**) have shown that all of the above quantities properly measured will give the same value of the damping capacity or logarithmic decrement provided the damping is small. The damping of most intact engineering materials may be considered small for this purpose; however, any deterioration of the material may remove it from this category.

Determination of Damping and Logarithmic Decrement

Two items of importance must be considered in computing damping factor and logarithmic decrement with Eqs. 6 and 9. The first is damping in the system other than in the specimen, and the second is the method of evaluating the shape of the resonance curve. Damping in the system may be either electrical or mechanical. Mechanical damping may occur in the supports of the specimen, driver, and pickup. If a speaker is used as a driver, some damping may occur in the support for the voice coil and at the point of contact of the plunger and specimen. Feed-back in an electromagnetic driver circuit may be particularly bad because the signal source may be affected. A circuit that will eliminate feed-back from the driver should be used. The driver and its circuit should be such that a constant driving force will be obtained as frequency changes. The measuring circuit should have a flat frequency response and zero or nearly zero phase shift.

If the points f_1 and f_2 in Eqs. 6 and 9 are to be located, the equipment must permit measurements of relative amplitude. A vacuum tube voltmeter has been used with some success. In this procedure the voltmeter scale indicates the magnitude of the signal at resonance, and the frequency is then adjusted to either side of resonance until the signal is reduced to 0.707 of its f_n value and then readings are taken giving f_n and f_2. Quimby (**13**) has used a Rayleigh disk suspended in air immediately off the end of a bar, vibrating longitudinally, to measure the amplitude of vibration. It is doubtful if this procedure is sufficiently accurate to permit a determination of the damping factor or logarithmic decrement. However, it should be sufficiently accurate to determine a reasonable value of resonant frequency from which the modulus of elasticity can be computed.

Decaying Amplitude Sonic Equipment

Resonance type sonic testing apparatus has also been used in which there is no attempt to maintain constant amplitude of vibration. In this method the specimen is energized by tapping with a hammer or with some other device. After the specimen has been struck, the resulting vibration is allowed to decay at its damped natural frequency. Under certain circumstances this frequency can be used in the formulas indicated above and the modulus of elasticity computed. Also if the amplitude between successive cycles can be determined, the logarithmic decrement can be easily computed, as indicated by Eq. 7 and Fig. 2.

Equipment for this type of test may be simple. Powers (**14**) was able to determine the natural frequency of a specimen by matching the sound with a suitable calibrated source of tone. He found a set of orchestra bells suitable within certain limits but was not able to determine damping. Grime (**15**) vibrated a specimen by tapping it on one end and then photographed from a cathode-ray oscilloscope its vibration patterns spread horizontally across the screen by a single transverse time base with superimposed 1 millisecond time marks. With such a photographic record it is possible to determine both the damping and the moduli of elasticity.

Olsson and Orlik-Ruckemann (**16**) used a device they called a "dampometer" in which it was possible to determine directly the logarithmic decrement and frequency of oscillations in the audio and subaudio frequency range. Such apparatus had definite advantages; for instance, it measures directly the natural frequency and the logarithmic decrement of a damped vibration, also giving a fairly accurate value for logarithmic decrement. While it is time-saving, the instrument is very complicated and expensive and is not applicable in the ultrasonic range.

Wave Velocity Methods

Equations for Mechanical Properties

Although vibration of a specimen at or near resonant frequency is the oldest method of sonic testing, another method using the velocity of sound waves in the material is rapidly gaining favor. In this method a sonic or ultrasonic sound wave is generated in a solid. Actually, three groups of waves are formed: compressional, shear, and surface waves, each traveling with a different velocity.

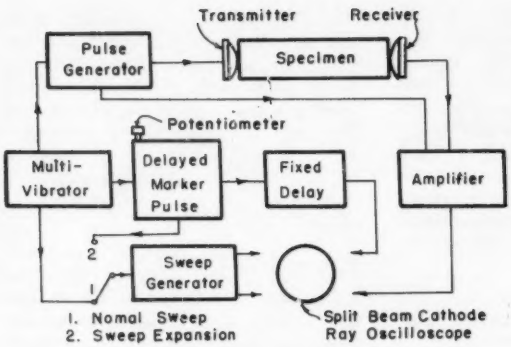

Fig. 4.—Soniscope.

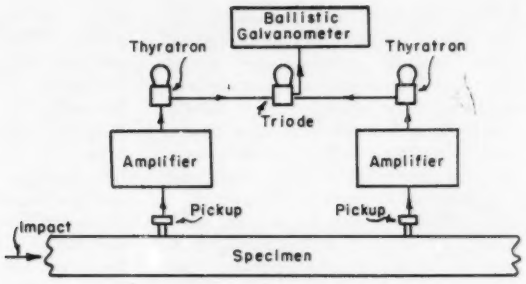

Fig. 5.—Interval timer.

They are commonly termed as longitudinal, transverse, and Rayleigh waves, respectively. The velocity of each wave is determined by the elastic constants and the density of the material. The compressional or longitudinal waves travel with the greatest velocity and are the ones generally used in determining the physical properties of various materials. These waves are most convenient to use because they arrive at the receiver prior to the other two and hence are not interfered with by them. Knowing the velocity of the compressional waves the dynamic modulus of elasticity can be computed by the following equation:

$$E_d = \rho V^2 (1 + \mu)(1 - 2\mu)/(1 - \mu) \quad (10)$$

where:

E_d = dynamic modulus of elasticity,
ρ = density,
V = compressional pulse velocity, and
μ = Poisson's ratio.

By observation of Eq. 10 it becomes apparent that the variations in Poisson's ratio affect the result to only a small degree and for practical purposes and for any one engineering material the terms involving μ may be considered a constant, B; the equation then becomes:

$$E = B\rho V^2 \quad (11)$$

In discussing methods for pulse testing, the pulse velocity is commonly referred to. The pulse velocity is generally the group velocity defined below, and it may differ from the wave velocity in the material. If a continuous vibration is traveling in an infinite mass, the individual cycles travel with the wave or phase velocity represented by the formula:

$$V = f\lambda$$

where:

V = the wave velocity,
f = the frequency, and
λ = wavelength.

Actually any pulsing of a material results in a wave group rather than a single wave being formed. The velocity of the initial steep wave front is taken as a criterion of group velocity which may be greater or less than the wave velocity and is described by the equation:

$$U = V - \lambda (dV/d\lambda)$$

where U is the group velocity.

If the wave velocity does not change with frequency, then $dV/d\lambda = O$ and $U = V$. Parshad (17) and Leslie and Cheesman (18) in tests on concrete have varied frequencies from 10,000 to 230,000 cps without observing any change in group velocity. This is believed to represent the conditions in many engineering materials; but even so, it should be remembered that the pulse technique measures the group velocity. If the wave velocity varies with frequency or wavelength, which is the case with continuously vibrating specimens, the two velocities will not be equal. Because of the above considerations the term "pulse velocity" has generally been used.

Soniscope

A commonly used appparatus for the pulse testing of concrete is called a soniscope, which is an electronic instrument developed to measure pulse velocity of high-frequency sound waves through solids. A diagram of the soniscope, as used by Leslie and Cheesman, is shown in Fig. 4. The soniscope propagates a sound wave into the concrete specimen by means of a piezoelectric crystal block transducer or driver, mechanically coupled through a castor-oil medium to a rubber diaphragm which is placed in contact with the specimen. At some distance from the first transducer, another transducer, the receiver, is placed. The amplified signal is then fed to a cathode ray oscilloscope which shows a vertical displacement as a result of the amplified signal. The time is measured electronically on the horizontal axis. This instrument is used rather widely but measures only the pulse velocity, and consequently only the modulus of a material can be determined. For a detailed review of pulse velocity technique and equipment for use in testing concrete the reader is referred to a paper by Whitehurst (19) presented before the Highway Research Board.

The soniscope has been used by Leslie and Cheesman, Whitehurst, Meyer (20), and others for determining the wave velocity in concrete. Generally speaking, the frequencies used are in the high-sonic or ultrasonic range. They vary from 20,000 to 250,000 cps. The high frequencies have one advantage over the low frequencies in that they are less affected by the dimensions of the specimen with regard to reflections, etc. However, the low frequencies have an advantage in that they may be used over longer distances in the specimen than the high frequency signals and still retain recognizable form. Higher frequencies cause less spreading of energy in the test specimen, though with lower efficiency. Rapidly repeated observations with the soniscope may be impossible because of the persistent reflections and refractions occurring in the specimen.

The soniscope has been slightly revised by Gatfield (21) and used by Jones (22) for tests on concrete. Gatfield reduced the pulse repetition rate from 100 to about 50 pulses per sec. The signals used by Leslie and Cheesman and Jones were made by using a tone generator in connection with a piezoelectric crystal. The soniscope has an advantage over the interval timer in that the wave form which is received is viewed on the cathode ray tube.

Interval Timer

In addition to the soniscope type of equipment, other devices are used for measuring pulse velocity. Long, Kurtz, and Sandenaw (23) reported on a device which is known as an electronic interval timer. This consisted of two

similar vibration pickups and amplifiers, two thyratron tube circuits, and a triode ballistic galvanometer circuit (Fig. 5). This device is very simple to operate. The pickups are merely placed on a concrete slab at a known distance apart and a hammer blow is applied to the concrete in a horizontal direction and in line with the two pickups. When the impulse reaches each pickup it triggers a thyratron, first starting, then stopping current flow through the galvanometer. The deflection of the galvanometer is directly proportional to the time required for the impulse to pass between the two pickups. Since the two supposedly similar circuits may actually be different, the device must be calibrated to determine its "zero" correction by making a number of tests with the pickup spaced at different intervals. If the interval values are plotted as the abscissa and the value of the galvanometer readings for each are plotted as the ordinate, a straight line drawn through the points obtained will intercept the ordinate axis at some value other than zero. This value is the correction time. Filter (**24**), in reporting the use of a similar microsecond interval timer, found that it was necessary to use a zero correction, determined by taking readings for at least two different distances between the pickups.

Morton (**25**) used a similar device but replaced the ballistic galvanometer circuit by a capacitor which was charged during the interval between pulses. The charge on the condenser was measured by a vacuum tube voltmeter circuit.

Anderson, Nerenst, and Plum (**26**) reported the development and use of a Condenser Chronograph very similar to the interval timers mentioned, differing in that the timing capacitor is charged to a known voltage prior to test. When the impact reaches and triggers the first pickup, the condenser commences to discharge through a known resistance; when the impulse operates the second pickup the discharge is stopped. The ratio of the final voltage to the original voltage is a direct measure of the time interval. In this case no calibration chart is taken, zero correction being taken into account by making at least five readings with the spacings of the pickups increased by regular intervals. Again the distances and measured times are plotted, and the ordinate intercept is then the "zero" correction.

Equipment Combining Soniscope and Interval Timer Features

The soniscope type of apparatus used an electronically produced pulse to develop sound waves in the specimen; the pulse is repeated as many as 100 cps. The electronic interval equipment uses only a single pulse developed generally by a mechanical blow which may vary and give variation in results unless the blow is controlled by a spring or similar mechanism. Equipment combining features of the interval timer and the soniscope have been developed. In this case the transmitter may be a small spring-driven hammer operated at approximately 5 blows per sec by a motor-driven cam. Instruments of this type generally use the cathode ray oscilloscope method of measuring time.

Chefdeville and Dawance (**27**) have developed such an apparatus in the Laboratories du Batiment et des Travaux Publics in Paris. A block diagram of their device is shown in Fig. 6. As may be seen from the figure, the hammer does not strike the concrete but rather an anvil which is in contact with the concrete. A detector on the anvil generates the signal which causes the trace of the oscilloscope to commence its sweep before the impulse reaches the concrete.

Minnick and Meyers (**28**) used portable equipment in their studies on lime-potash-soil compositions employed in road constructions. An acoustical pulse was generated by a thyratron-driven electronic hammer, which strikes a target at the rate of approximately 3 times a second. Bozorth, Mason, and McSkinin (**29**) studied the frequency dependence of the elastic constants in nickel crystals by using an ultrasonic pulsing method with a frequency of about 10 Mc (Fig. 7).

Standing Wave Method

In addition to the soniscope and interval-timer, other devices are used for measuring sound velocity. An early method for measuring wave velocity of sound in concrete was developed by Long and Kurtz (**10**). They used a converted auditorium loud speaker driven by a variable frequency oscillator. The plunger connected to the speaker cone was rigidly attached to the concrete to be tested. A vibration pickup and oscilloscope were used to analyze the wave forms developed in the concrete. The oscillator was fed to one pair of plates of the oscilloscope while a signal from the vibration pickup was fed to the other plates. Lissajous figures were used to indicate the phase relationship of the two signals. To make a test, the pickup was placed on the concrete and then moved away from the speaker along a radial line until the oscilloscope pattern indicated a 180 deg phase shift. From the distance through which the pickup had been moved and the frequency, the wave velocity was computed: the distance through which the pickup had been moved being equal to $\frac{1}{2}$ wave length of the known frequency in the concrete.

Discussion

The resonant frequency method is quite useful but is applicable for laboratory specimens only, meaning that the specimens must be of certain sizes and shapes in order that a convenient test

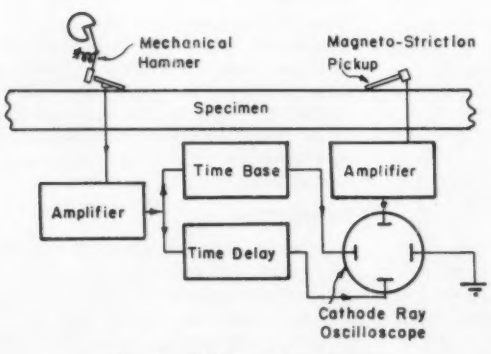

Fig. 6.—Repetitive blow device.

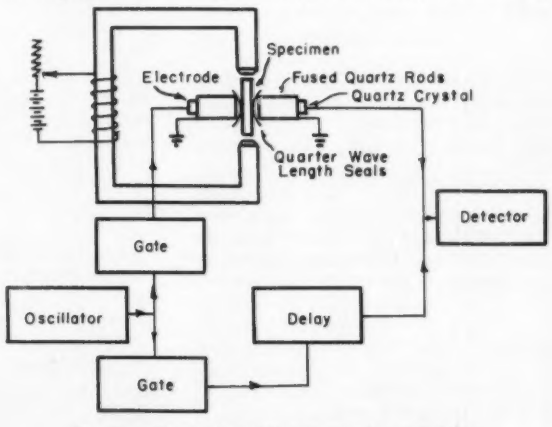

Fig. 7.—Ultrasonic pulsing measuring apparatus.

may be made. The wave velocity or pulse velocity methods may be used with almost equal facility in the field and laboratory, since within reasonable limits the method does not depend on the size or shape of the specimen. This is a distinct advantage in studying structures and machine parts.

Although the various sonic tests may be used to obtain the same information, the results obtained may not be identical. For instance, Batchelder and Lewis (**30**) have found in tests on concrete that the velocity modulus of elasticity seemed always to be greater than the transverse or longitudinal modulus of elasticity. This lack of agreement is probably not due to material variation, since multiple tests of the same type will give reasonably consistent results. The greatest source of error may be in the determination of dimensions and shape factors. In many of the working formulas the length and diameter are used to second or higher powers, so extreme care is required in their determination. The relaxation time of the material may be important in the case of transverse vibration, but the higher frequencies used in longitudinal vibration or pulse testing may eliminate that problem.

Occasionally where there has been a relationship between some property which can be determined by sonic methods and other properties, attempts have been made to correlate the results of the sonic tests directly with those other properties. As an illustration, the strength and rheological behavior of concrete have been predicted by using the logarithmic decrement in conjunction with dynamic modulus (**31**, **32**).

The methods discussed are primarily related to low-frequency (up to 200 kcs) techniques and different equipment and methods are needed above this frequency. For example, shear waves, surface waves, interferometers, Reflectoscopes, etc., would be applicable when these determinations are made at frequencies about 200 kcs. At these higher frequencies losses are primarily scattering as opposed to friction or viscosity losses which are predominant at the lower frequencies.

Before deciding whether to use a sonic or static method for determining the mechanical properties of a material, some consideration should be given to the purpose for which the properties will be used. In many cases dynamic procedures may offer advantages through the use of small specimen, rapidity, and extreme sensitivity. However, static tests may be needed for data to be used by engineers to assess properly the effects of stress and the extent of the elastic region.

Acknowledgment:

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Stress-Corrosion Cracking of Insulated Austenitic Stainless Steel*

By A. W. DANA, JR.

The phenomenon of stress-corrosion cracking which may occur when austenitic stainless steels are exposed to moist thermal insulating materials is believed to result from the action of water-soluble chlorides leached from the insulations. Chemical analyses showed that water-soluble chlorides are present in 85 per cent magnesia, calcium silicate, and glass fiber insulating materials, with little difference in chloride level between them. Simulated service tests indicated that 85 per cent magnesia insulation had the greatest tendency to produce cracking at 100 C. After 200 days of exposure, no statistically significant difference in cracking tendency was present between calcium silicate and glass fiber insulations.

Fig. 1.—Illustration of factors involved in stress-corrosion cracking under thermal insulation.

Austenitic stainless steels may be defined as those chromium-iron alloys to which sufficient nickel has been added to retain the austenite phase[1] at ambient temperatures. These steels are used throughout the chemical industry because of their excellent resistance to chemical attack. However, failures of austenitic stainless steels by stress-corrosion cracking can occur when certain conditions of stress and environment are present.

Stress-corrosion cracking of austenitic stainless steels is often associated with chloride-bearing environments and the presence of stress, residual or applied. The corrosive environment by itself usually produces only mild general corrosion. However, under the influence of stress, the corrosion concentrates along relatively few paths, and penetration of the steel becomes rapid. Thus, stress-corrosion cracking causes equipment to fail much sooner than by corrosion alone, and at stresses that, by themselves, would not be damaging.

A number of investigators (**1, 2, 3, 4, 7**)[2] have described failures of austenitic stainless steel equipment by stress-corrosion cracking. The exposure conditions under which these failures occurred vary widely, from city water to industrial process media. In all cases, the failed part had been subjected to stress. This discussion is concerned with the specific case (**2**) where thermal insulation was used over austenitic stainless steel piping or tubing operating at temperatures from 50 to 110 C, and the insulation became wetted. This cracking has been attributed to the action of water-soluble chlorides leached from the insulation (**2**).

The leaching process can be visualized by reference to Fig. 1. The water for the leaching action can originate as rain

ARTHUR W. DANA, JR., research project engineer at the E. I. du Pont de Nemours & Co. Engineering Department's Engineering Research Laboratory, has engaged in research on the phenomenon of stress-corrosion cracking of austenitic stainless steel since 1954. He is active on the stress-corrosion task force of subcommittee IV of ASTM Committee A-10 on Iron, Chromium-Nickel, and Related Alloys.

* Presented at the Symposium on Thermal Insulating Materials, Philadelphia, Feb. 6, 1957.
[1] Solid solution of alloying elements in gamma or face-centered cubic iron.
[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

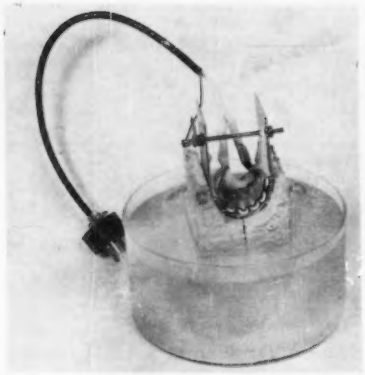


Fig. 2.—Experimental method for determining tendency of insulation materials to stress corrosion crack austenitic stainless steels (× 0.5).

water or as a steam leak. The water, on passing through the insulation, leaches out the water-soluble chlorides. At the hot surface of the equipment, the water-soluble chlorides are concentrated by evaporation of the water. In this manner, environmental conditions for stress-corrosion cracking of austenitic stainless steels are established.

At least 40 failures of austenitic stainless steel process equipment within the du Pont Co. have been traced to the thermal insulation. In each case, failure of the piping or vessel was initiated at the surface covered with the insulation. Where chemical analyses of the deposits on the metal surfaces were available, chloride contents as high as 3 to 5 per cent have been found. This is in contrast to less than 0.5 per cent chlorides present in the insulation on a bulk basis. In one instance, an austenitic stainless tower failed after two years' service at 100 C. Stress-corrosion cracking started on the outside of the column about 3 to 6 ft from the top. The tower had been lagged with 85 per cent magnesia insulation and was exposed to rain water.

In the above cases, austenitic stainless steels were specified as the materials of construction because of the corrosive requirements of the process streams. Therefore, substituting an alternate material not susceptible to stress-corrosion cracking in chloride environments was not an acceptable solution to prevent the occurrence of failures unless the corrosion resistance and cost were comparable to stainless steel.

Three types of thermal insulating material are normally used where service temperatures range from 50 to 110 C: 85 per cent magnesia, calcium silicate, and glass fiber. The 85 per cent magnesia insulation material consists of a minimum of 85 per cent by weight of hydrated, basic magnesium carbonate reinforced with mineral fiber. Calcium silicate insulation contains 55 per cent or more by weight of hydrous calcium silicate reinforced with mineral fiber. Glass fiber insulations usually are silica glass fibers reinforced with a resin binder. These three materials were studied in the present investigation.

The primary objective of the experimental program was that of determining whether moist samples of 85 per cent magnesia, calcium silicate, and glass fiber insulating materials would cause stress-corrosion cracking of austenitic stainless steels. As a necessary adjunct to this program, the chloride contents of samples of the three insulating materials were determined.

Material and Procedure

Chloride analyses were performed by an independent testing laboratory employing standard gravimetric techniques. Unused insulation samples were obtained in box lot quantities from as many sources as possible. Both the edge and center of the block and pipe insulation samples were analyzed for total and water-soluble chlorides.

After completion of a test, samples of the surface residues were scraped from the stainless steel specimens and analyzed for their chloride contents.

In the test method, Fig. 2, the block of insulation acts as a wick, drawing the deionized water up from the dish to the specimen surface. Water-soluble chlorides are leached from the insulation as the water travels from the dish to the specimen. At the specimen surface, the chloride concentration of the water solution is increased by evaporation, in many cases to dryness. Specimen temperatures are controlled to within ±3 C by varying the current flow through the resistance heater which is taped to the curved portion of the specimen. Power input is controlled by a transformer. The U-bend specimen is stressed by tightening the bolt assembly.

Annealed 16-gage ($\frac{1}{16}$-in. thick) type 304 stainless steel (0.06 carbon, 0.54 silicon, 0.59 manganese, 18.32 chromium, 8.97 nickel) sheet stock was used for the U-bend specimens. Specimens 2 in. wide by 7 in. long were sheared from the sheet with the 7-in. dimension taken parallel to the rolling direction. The sheared edges and one flat surface were ground wet on a 80 grit belt (the ground surface was exposed to the insulation). A 1-in. radius bend was placed in the center of the specimen utilizing a precision bender. The head of the bending machine was modified so that a roller did the bending rather than a friction arrangement which is normally used. In this manner, scratching and scoring were minimized. A jig was used for drilling the holes and to check that specimens had been uniformly bent.

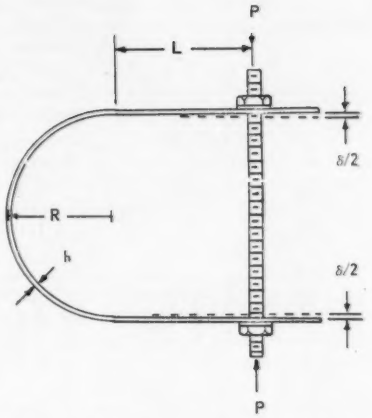


Fig. 3.—Measurements required for deflection calculations.

$$\delta = \left[\frac{12S(2R+h)}{(L+R)(8R+h)(h)(E)}\right] \cdot \left[\frac{L^3}{3} + R\left(\frac{\pi}{2}L^2 \frac{\pi}{4}R^2 + 2LR\right)\right]$$

δ = Deflection, in.
S = Applied stress, psi
E = Modulus of elasticity, psi
R = Radius of bend, in.
h = Thickness, in.
L = Length straight section, in.

A maximum stress of 30,000 psi at the apex of the bend was chosen for the entire experimental program. This stress is approximately 95 per cent of the yield strength of the annealed type 304 stainless steel. The necessary deflection to induce this stress at the bend was calculated by means of a formula derived from the theory of elasticity. Deflections were measured from the rest position of the U-bend specimen. The formula is given below and the measurements needed in Fig. 3.

$$\delta = \left[\frac{12S(2R+h)}{(L+R)(8R+h)(h)(E)}\right] \left[\frac{L^3}{3} + R\left(\frac{\pi L^2}{2} + \frac{\pi R^2}{4} + 2LR\right)\right]$$

where:

δ = deflection, in.,
S = applied stress, psi,
E = modulus of elasticity, psi,
h = thickness, in.,
R = radius of bend, in., and
L = length of straight portion, in.

Calculations of the deflections are obviously long and tedious. By using fixtures and employing careful bending procedures, it was possible to bend specimens to close tolerances. As a result, it

TABLE I.—CHLORIDE ANALYSES[a] OF INSULATIONS.

Manufacturer	*Total Chlorides*		*Water Soluble Chlorides*	
	Edge	Center	Edge	Center
85 PER CENT MAGNESIA				
A	0.17 to 0.23	0.10 to 0.25	0.13 to 0.22	0.05 to 0.22
B	0.15 to 0.22	0.10 to 0.24	0.12 to 0.20	0.05 to 0.21
C	0.22 to 0.26	0.21 to 0.25	0.19 to 0.25	0.20 to 0.24
D	0.44 to 0.55	0.45 to 0.54	0.35 to 0.46	0.33 to 0.51
E	0.27 to 0.33	0.09 to 0.33	0.27 to 0.32	0.05 to 0.32
F	...	0.05 to 0.10	...	0.03 to 0.09
CALCIUM SILICATE				
G	0.42 to 0.47	0.43 to 0.48	0.38 to 0.44	0.40 to 0.45
H	0.21 to 0.29	0.04 to 0.25	0.20 to 0.22	0.04 to 0.22
I	0.16 to 0.33	0.15 to 0.33	0.15 to 0.32	0.15 to 0.32
J	0.18 to 0.19	0.06 to 0.20	0.16 to 0.18	0.02 to 0.17
K	...	0.08 to 0.19	...	0.04 to 0.18
L	...	0.05 to 0.13	...	0.02 to 0.11
GLASS FIBER				
M	0.29 to 0.33	0.27 to 0.32	0.03 to 0.06	0.03 to 0.10
N	0.33 to 0.42	0.30 to 0.40	0.26 to 0.33	0.24 to 0.29
O	0.12 to 0.14	0.11 to 0.15	0.09 to 0.10	0.08 to 0.10
P	...	0.05 to 0.55	...	0.01 to 0.50
Q	...	0.10 to 0.13	...	0.06 to 0.10
R	...	0.10 to 0.19	...	0.09 to 0.15

[a] Per cent by weight, dry basis, as chlorides.

was necessary only to recheck these measurements every 5 specimens to insure uniformity.

The use of a U-bend specimen places limitations, which have been described by other investigators (6), on the test method. However, its application here is to screen environments, the thermal insulation materials, for tendency to promote stress-corrosion cracking. For this purpose, the test is believed adequate and has the advantage of low cost and permits running many tests simultaneously.

Specimens have been exposed at 100, 80, 60, and 40 C. The results at 100 C have been nearly completed and, therefore, comprise the major portion of the data presented. However, preliminary results at the other temperatures are included.

During each test, the incidence of cracking was observed as a function of exposure time. Specimens were checked each day during the first few weeks of exposure and then at longer time intervals. Specimens were examined using a binocular microscope at magnifications up to 50 diam. Cracking was predominately associated with black or reddish black deposits (corrosion products) along the cracks.

Deionized water which contained no measurable amounts (<0.05 ppm) of chlorides was added to the dishes twice daily. The average daily consumption of water was 1500 ml for the 85 per cent magnesia and calcium silicate and 2000 ml for the glass fiber samples.

Results and Discussion

Chloride Analyses

Chloride analyses of the three types of insulation studied are listed in Table I. In each case, ranges of chloride contents are given since samples were obtained from more than one source for a given type and supplier. No significant difference was noted in the chlorides present in the edge and center of the block or pipe samples. On the other hand, considerable variations were present for different samples from a given manufacturer and between manufactures of each type of insulation material.

The results of the chloride analyses are summarized in Table II. Comparing the three insulation types, two points are evident: (1) all of the thermal insulations analyzed contained water-soluble chlorides, and (2) for practical purposes, there was very little difference in the ranges of chloride contents for the three types. These data emphasize the necessity of defining the relative susceptibility of austenitic stainless steel to stress-corrosion cracking as a function of exposure to the various insulating materials.

TABLE II.—SUMMARY OF CHLORIDE ANALYSES[a]

Insulation Type	Range in Water-Soluble Chloride	Average Water-Soluble Chloride Content
85 per cent magnesia	0.05 to 0.51	0.16
Calcium silicate	0.02 to 0.45	0.17
Glass fiber	0.01 to 0.50	0.17

[a] Per cent by weight, dry basis, as chlorides.

Preliminary Cracking Tests

Preliminary tests were conducted at 100 C specimen temperatures to evaluate the tendency of the various insulating materials to cause stress-corrosion cracking of type 304 austenitic stainless steel (standard material for this investigation). For these tests, the apparatus shown in Fig. 2 and previously described was used. The data from these tests are summarized in Table III.

In Table III note that of the six 85 per cent magnesia insulations tested, five produced cracking. In contrast, only two of the five calcium silicate insulations tested caused stress-corrosion cracking of the type 304 stainless steel specimens. Both specimens exposed to

TABLE III—PRELIMINARY STRESS-CORROSION CRACKING TESTS AT 100 C.

Insulation Type	Manufacturer	Exposure[a] Time, Days	Results	Chloride Content New Insulation, per cent by Weight	Chloride Content Deposits Scraped from Specimens, per cent by Weight
85 per cent Magnesia	A	266	Cracked	0.05 to 0.22	0.41 (8.1)
85 per cent Magnesia	B	7	Cracked	0.05 to 0.21	0.33
85 per cent Magnesia	C	44	Cracked	0.20 to 0.24	1.83
85 per cent Magnesia	D	160	No cracks, Pitting	0.33 to 0.51	0.43
85 per cent Magnesia	D	218	Cracked	0.33 to 0.51	...
85 per cent Magnesia	E	160	No cracks, Pitting	0.05 to 0.32	0.85
85 per cent Magnesia	F	39	Cracked	0 03 to 0 09	0 34
Calcium silicate	G	204	Cracked	0.40 to 0.45	1.22
Calcium silicate	H	160	No cracks	0.04 to 0.22	0.25
Calcium silicate	I	162	No cracks	0.15 to 0.32	0.34
Calcium silicate	J	162	No cracks	0.02 to 0.17	0.20
Calcium silicate	L	96	Cracked	0.02 to 0.11	0.51
Glass fiber	P	9	Cracked	0.01 to 0.50	...
Glass fiber	P	348	Cracked	0.01 to 0.50	...

[a] If specimen cracked, days for cracking to occur listed. Where no cracking was observed, test terminated at indicated exposure time.

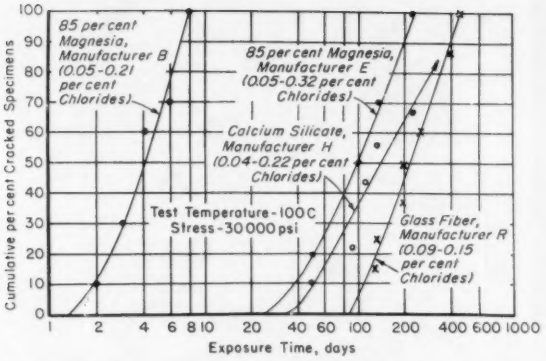


Fig. 4.—Multiple cracking tests on type 304 stainless steel specimens exposed to samples of three types of insulation.

the one manufacturer's glass fiber insulation were cracked. The fact that for both the 85 per cent magnesia and calcium silicate insulations some manufacturers' insulation caused cracking, while others did not, suggested that differences in cracking tendency exist between sources of a given insulation type. This difference cannot be rationalized by comparing the chloride analyses of the insulations. The 85 per cent magnesia insulations that did not cause cracking within 160 days exposure time contained the highest chloride contents, up to 0.51 per cent. On the other hand, one manufacturer's insulation that did crack the stainless specimen within 39 days contained the lowest amount of chlorides—0.03 to 0.09 per cent. Similar results were obtained on the calcium silicate insulation.

Considering now the variations in cracking times observed among samples of the three insulation types, the time for cracking for the 85 per cent magnesia insulations varied from 7 to 266 days, while that for the calcium silicate ranged from 96 to 204 days where stress-corrosion cracking occurred. The one glass fiber insulation caused cracking in 8 to 348 days. While not conclusive, these results indicated that differences in cracking behavior may exist between the three types of thermal insulation.

No correlation was apparent between the chloride contents of the deposits scraped from the specimens after termination of the tests and the incidence of cracking. The relatively low chloride concentrations found in the deposits probably reflected dilution effects caused by particles of the insulation sticking to the specimen. In one case (85 per cent magnesia from manufacturer A), it was possible to obtain a sample adjacent to the cracked area free from appreciable amounts of insulation. This sample contained 8.1 per cent chlorides *versus* a bulk average for the deposit of 0.41 per cent. The data for the chloride contents of the surface deposits given in Table III indicated that chlorides were concentrated at the specimen surface to a level higher than that present in the insulations. However, the actual chloride analyses were not directly comparable with each other as a result of errors involved in sampling.

While these preliminary results indicated that differences in cracking behavior may exist between the three types of thermal insulation and between sources of a given type, the question was posed whether these differences were real or due to scatter inherent in the test procedure.

Multiple Cracking Tests

To statistically check the differences in cracking behavior noted in the preliminary tests, 10 duplicate tests were run at 100 C specimen temperatures with selected samples of each insulation type. The results are summarized in Fig. 4. The 85 per cent magnesia insulation from manufacturer B was chosen because this insulation produced cracking of the type 304 stainless steel specimens within the shortest period in the preliminary tests. The other three insulations were selected for two reasons: (1) their chloride contents were comparable, and (2) neither the 85 per cent magnesia insulation from manufacturer E nor the calcium silicate insulation from manufacturer H caused cracking in the preliminary tests.

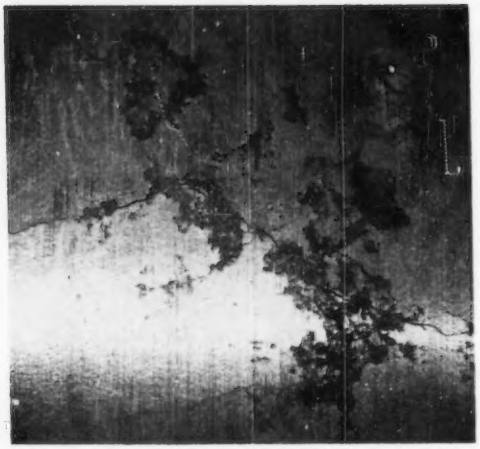
The curves in Fig. 4 were obtained by plotting the number of cracked specimens in cumulative per cent as a function of test time measured in days. Consider the curve for the 85 per cent magnesia insulation from manufacturer B. After 3 days exposure time, 3 of the 10 specimens had cracked. After 6 days, 5 more specimens had cracked or a total of 8 specimens. All 10 specimens were cracked in 8 days.

The positions of the four curves from left to right show the relative cracking tendency of the four insulation materials. For example, the 85 per cent magnesia insulation from manufacturer B obviously has the strongest cracking tendency. Comparing now the two 85 per cent magnesia insulations from different manufacturers, a significant difference in cracking behavior is noted. This behavior is not related to the chemical contents of the two materials, for chemical analyses did not show any significant differences in chemical content. In fact, the chloride content of the 85 per cent magnesia insulation from manufacturer B on the average was lower than that from manufacturer E. On the other hand, the chloride contents of deposits scraped from four of the ten U-bend specimens tested were consistently higher for the insulation from manufacturer B which caused cracking in the shortest exposure time. The analyses were 4.20, 3.00, 20.00 and 1.60 per cent by weight *versus* 1.07, 0.86, 0.51, and 1.20 per cent for insulation E. These analyses suggest that chlorides are more readily leached from the 85 per cent magnesia exhibiting the shortest cracking time. Why this is the case is not clear.

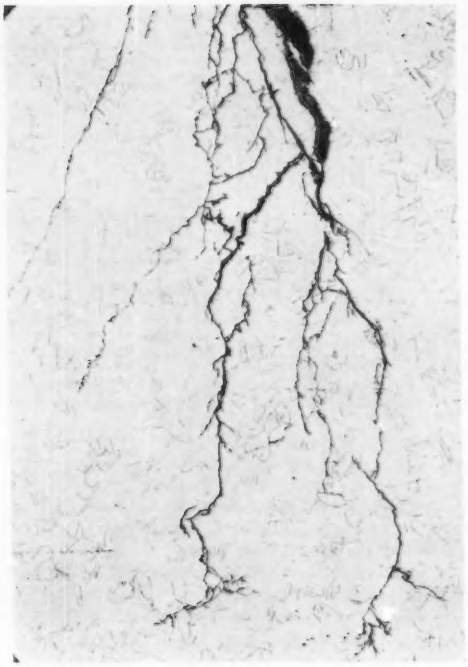
Turning now to the curves for the calcium silicate and glass fiber insulations, a statistically significant difference in cracking tendency is noted up to 100 days exposure time. At longer times, this difference becomes less pronounced.

The data shown in Fig. 4 indicate that all three types of thermal insulation, 85 per cent magnesia, calcium silicate, and glass fiber, will cause cracking of austenitic stainless steels if the insulation becomes wetted and the exposure time is sufficiently long. No correlation is apparent between the time for cracking and the chloride content of the three insulation types. The presence of water-soluble chlorides appears to be a sufficient condition for cracking.

To evaluate further whether the presence of chlorides in the insulation is necessary for cracking to occur, a block of the 85 per cent magnesia insulation from manufacturer B was soaked in a solution of silver nitrate. Silver chloride is only slightly soluble in water ($<1\times10^{-4}$ g per ml). After treating with silver nitrate, no cracking has been observed after 264 days exposure. The untreated blocks caused cracking in 8 days or less under the same conditions. Thus, the presence of water-soluble chlorides must be considered a major factor contributing to the stress-corrosion cracking of austenitic stainless steel by moist thermal insulation.

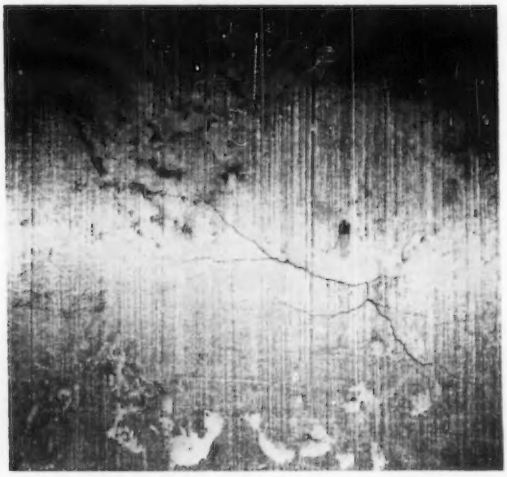


(*a*) Appearance of cracks on surface of specimen (×6).

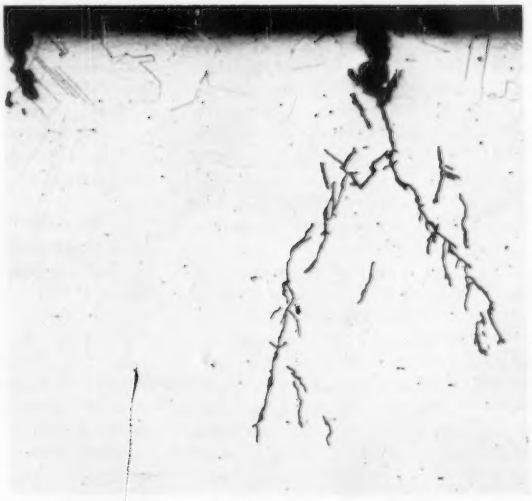


(*b*) Aqua regia etch (×100). Cross-section of specimen showing penetration of cracking.

Fig. 5.—Stress-corrosion cracking of type 304 stainless steel specimen exposed to 85 per cent magnesia insulation at 100 C.



(*a*) Surface cracks (×6).



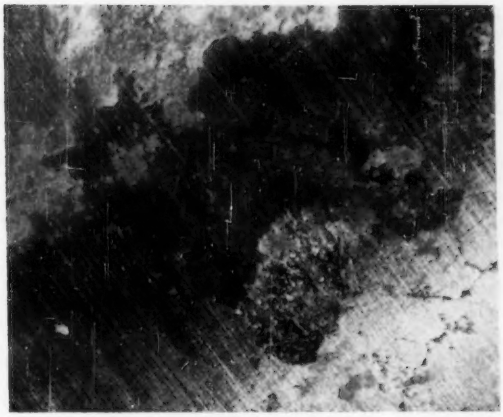
(*b*) Aqua regia etch. Cross-section of specimen. Note branching cracks (×250).

Fig. 6.—Stress-corrosion cracking of type 304 stainless steel specimen exposed to calcium silicate insulation at 100 C.

Effect of Specimen Temperature

Temperature has two effects in the present investigation. Temperature has a direct influence on the stress-corrosion cracking process. Hoar and Hines (5) have reported that changes in temperature on the order of 10 C can result in a twofold increase in time to failure of austenitic stainless steels exposed to concentrated $MgCl_2$ solutions. Specimen temperature also will directly influence the rate of evaporation of the water in the experimental method used in this investigation. The rate of evaporation not only controls the concentration of chlorides at the specimen surface but also the amount of water drawn through the block of insulation. This latter factor depends on the continual removal of water at the top of the block to provide the driving force for the wicking action.

Experiments are in progress at 80, 60, and 40 C specimen temperatures with the same four insulation materials studied in the multiple cracking tests. Only the 85 per cent magnesia insulation from manufacturer B has caused cracking of the type 304 stainless steel specimens to date. This cracking occurred at an 80 C specimen temperature after 183 days exposure. At 100 C specimen temperature, consistent cracking was



(*a*) Surface cracking. Note pitting associated with cracking (×6).

(*b*) Aqua regia etch. Cross-section of specimen. Note small surface cracks (×250).

Fig. 7.—Stress-corrosion cracking of type 304 stainless steel specimen exposed to glass fiber insulation at 100 C.

observed in 8 days or less on exposure to this insulation material. All of the specimens have been in test for at least 293 days. These preliminary data indicate that temperature has a pronounced influence on the incidence of stress-corrosion cracking of insulated austenitic stainless steel equipment.

Metallographic Examination

The stress-corrosion cracks noted on the surface of the specimens were usually very fine (Figs. 5(*a*), 6(*a*), and 7(*a*)) and often associated with black corroded areas and pitting attack. The cracks are branched and can occur at many sites. On propagating through the cross-section of the specimens (Figs. 5(*b*), 6(*b*), and 7(*b*)), the cracks take a "lightning-like" pattern that is transgranular.

Examination of the surface layers of the specimens after polishing showed that the main cracks often started from areas where preferential corrosion attack had occurred (Fig. 8). These areas of preferential corrosion attack appeared to be slip lines or deformation bands formed in the distorted surface layer of the specimens. After the corrosion had proceeded sufficiently far, a pit-like depression formed from which larger cracks propagated. These data may provide a clue to the mechanism of crack initiation. The relation of the observed preferential corrosion attack

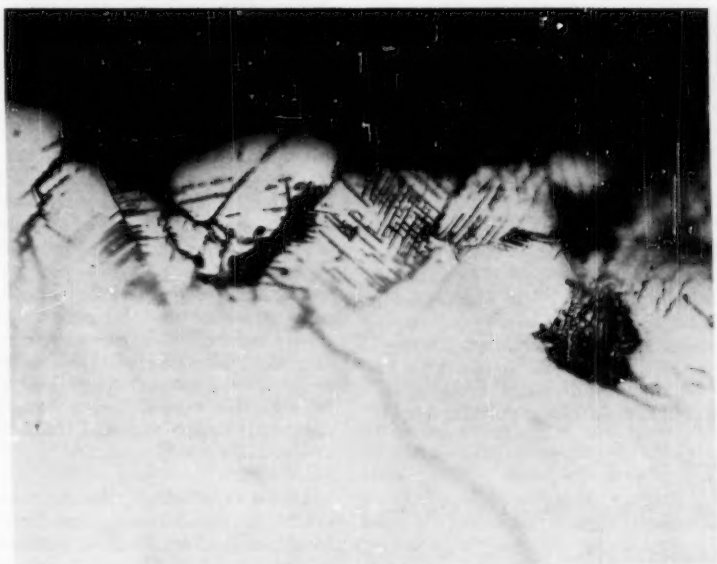


Fig. 8.—Surface of specimen exposed to 85 per cent magnesia insulation. Note main crack starting from corroded deformation lines. Unetched (×1000).

in the surface layers and the crack initiation process will be studied in another program.

Summary and Conclusions

The phenomenon of stress-corrosion cracking which may occur when austenitic stainless steels are exposed to moist thermal insulating materials is believed to result from the action of water-soluble chlorides leached from the insulations. Therefore, the leaching reaction and the mechanism by which chlorides are concentrated at the surface of the specimen or equipment are of primary importance in determining the exposure time required for cracking. Translation of cracking times observed in laboratory tests into service cracking times remains to be done.

The data obtained from chemical analyses and exposing stressed type 304 stainless steel U-bend specimens to samples of 85 per cent magnesia, calcium silicate, and glass fiber insulating materials in a simulated service test indicated the following:

1. Water-soluble chlorides are present in all three types of thermal insulation, with little difference in chloride level between them.
2. No correlation exists between chloride content of the insulating materials and time for cracking of type 304 stainless steel.
3. The 85 per cent magnesia insulation had the greatest tendency to produce cracking at 100 C specimen temperature. After 200 days exposure, no statistically significant difference in cracking tendency is present between the calcium silicate and glass fiber insulations tested.
4. Exposure temperature has a pronounced influence on the incidence of stress-corrosion cracking of specimens in contact with moist insulation materials.

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(5) T. P. Hoar and J. G. Hines, "The Stress-Corrosion Cracking of Austenitic Stainless Steels: Part I—Mechanism of the Process in Hot Magnesium Chloride Solutions," *Journal*, Iron and Steel Inst., Vol. 182, pp. 124–143 (1956).

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(7) M. A. Scheil, "Some Observations of Stress-Corrosion Cracking in Austenitic Stainless Alloys," Symposium on Stress-Corrosion Cracking of Metals, Am. Soc. Testing Mats. pp. 395–410. Disc., 432 (1945). (Issued as separate publication *ASTM STP No 64*, published jointly with The Am. Inst. of Mining and Metallurgical Engrs).

DISCUSSION

MR. F. N. ALQUIST.[1]—What effect on chloride content would heating in steam for one week have?

MR. A. W. DANA, JR. (*author*).—Steam is an excellent leaching agent. In fact, as I mentioned in the introduction, a considerable number of failures have been experienced in the vicinity of steam leaks. Application of a "steam cleaning" treatment to remove chlorides from insulation materials, however involves the requirement that the chloride be carried out of the insulation with the steam. Whether this could be practically carried out to make chloride-free insulation, I am not prepared to answer.

MR. W. J. SAUBER.[2]—My interest has been primarily in the plastics field. In discussing the variables of stress cracking in stainless steel, we noted they were the same as those we encounter in the environmental stress cracking of plastic materials such as polyethylene or polystyrene. This is in the line of a question and yet somewhat of an offering of some of our experience with environmental stress cracking of polystyrene.

We have tried to develop a test which would account for these same variables which you have encountered also. What we do is vary the stress under controlled conditions until we have reached that point or critical stress above which the material will crack and below which it will not.

I noticed that you stressed a part by bending it in a U-shaped form. We bend the plastic over an elliptical section which, by having a variable radius, produces a variable stress. This varying radius produces a high stress on one end of our so-called bending form and a low stress on the other end, varying proportionately in between. We can then determine the so-called critical stress of the plastic stressed in this manner. We wonder if you have investigated this approach and, if not, am offering this for your use.

MR. DANA.—To date, the question of whether a critical stress exists for the stress-corrosion cracking of austenitic stainless steels remains in doubt. In our work, we were primarily interested in the environment, the thermal insulation, and for that reason have not studied the effect of applied stress.

MR. WILLIAM S. ELLIOTT.[3]—Three commonly used insulating materials of the premolded type have been mentioned as being unsuited for the protection of stainless steel pipe at elevated temperatures. There are many insulating materials which could be molded and which do not contain calcium chloride. Would there be a good market for such products if developed for high-temperature pipe insulation?

MR. DANA.—We have not ruled out product development of new materials as a solution to the problem. However, chlorides are common in nature and we have analyzed materials other than calcium silicate and glass fiber and have yet to find one that did not contain chlorides. One must realize that we are dealing with a situation where a minor constituent of the environment becomes the major constituent contributing to the cracking process. Chloride contents measured in the ppm range can cause the stress-corrosion cracking of austenitic stainless steels. At the same time I am sure that if a chloride-free insulation were produced there would be a market for it.

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[1] E. C. Britton Research Lab., The Dow Chemical Co., Midland, Mich.

[2] Plastics Technical Service, The Dow Chemical Co., Midland, Mich.

[3] Secretary-treasurer, The Vermiculite Assn., Inc., Rego Park, L. I., N. Y.

A New and Rapid Method for

Determining Unhydrated Magnesia in Dolomitic Lime Hydrates

By EMIL TRATTNER

This method gives reproducible results that substantially agree with those obtained by the costly and time-consuming standard chemical-analysis method

THE EARLY work of Wells and Taylor (1)[1] seemed to indicate that a maximum limit on the unhydrated oxides in a hydrated lime would be desirable. An arbitrary limit of 8 per cent unhydrated oxide was proposed in the Tentative Amendment to Federal Specification SS-L-351, dated Feb. 2, 1940. This limit was subsequently specified in ASTM Specifications C 206[2] and C 207.[3] These specifications recognize two types of hydrated lime, namely type N, or normal hydrate, and type S, or special hydrate. Type S is differentiated from type N mainly in that a limitation on the unhydrated oxides is specified for type S.

The method for determining the unhydrated oxides is set forth in ASTM Methods C 25, Chemical Analysis of Limestone, Quicklime, and Hydrated Lime.[4] This method requires a chemical analysis for the main constituents of the hydrated lime, and the unhydrated oxides are calculated from the values obtained. The unhydrated oxide calculation depends on the assumption that in the process of hydration the CaO hydrates preferentially and, in the case of dolomitic lime hydrate, the CaO is completely hydrated while the MgO is but partially hydrated. The calculated combined H_2O is, therefore, apportioned so as to satisfy all the CaO, the rest of the H_2O is assigned to its equivalent of MgO, and the resultant remainder of the MgO is assumed to be unhydrated.

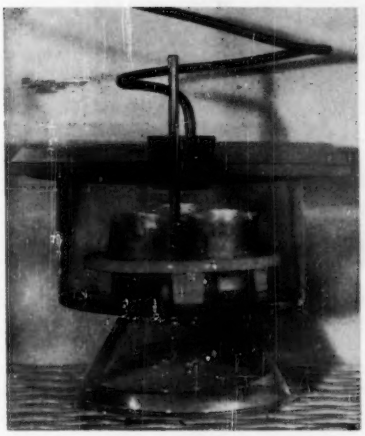

Fig. 1.—CO_2-free drying apparatus, inside oven.

The required chemical analysis is expensive and time-consuming. Should the prospective purchaser have no interest in the chemical composition but be primarily interested in the free MgO content of the lime, he would have no option to forego chemical analysis. It seemed desirable, therefore, to provide an easy, rapid test to determine the unhydrated MgO content. The purchaser would then have the option of either a complete chemical analysis or a rapid free MgO determination. Free MgO control at the plant would also be greatly facilitated.

It was reasoned that a rapid test method could be developed based on the forced hydration of the unhydrated MgO by high-pressure steam in a standard autoclave. We could assume that each molecule of H_2O that the lime hydrate acquired was the result of the hydration of one molecule of free oxide. If the same assumption is made as in the standard chemical analysis method that the CaO was already completely hydrated, only the free MgO could be responsible for the gain in H_2O. By determining the gain in H_2O, the free MgO could be easily derived.

EMIL TRATTNER, engineer, Concreting Materials Section, National Bureau of Standards, formerly held research fellowships at the Bureau of Standards from the National Lime Assn. and the National Academy of Sciences for research on cement-lime and masonry cement mortars, respectively; is currently engaged on research on the permeability of concretes and mortars and on improving test methods for lime and lime-pozzolan mixtures.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

[2] Specification for Special Finishing Hydrated Lime (C 206-49), 1955 Book of ASTM Standards, Part 3, p. 213.

[3] Specification for Hydrated Lime for Masonry Purposes (C 207-49), 1955 Book of ASTM Standards, Part 3, p. 215.

[4] Methods of Chemical Analysis of Limestone, Quick-lime and Hydrated Lime (C 25-47), 1955 Book of ASTM Standards, Part 3, p. 241.

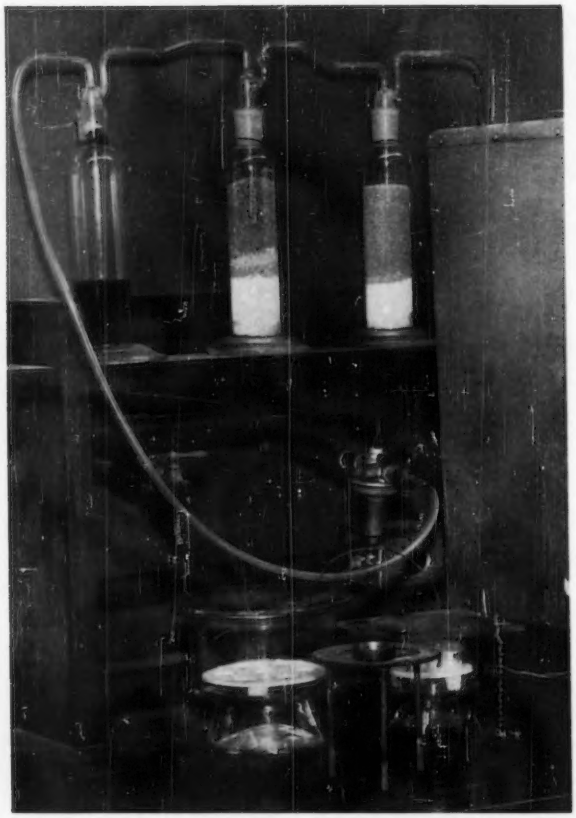

Fig. 2.—CO_2-absorption train, outside oven.

To ascertain the gain in H_2O, the lime must be dried, before and after hydration, to the same degree of dryness. In addition, after the initial dry weight has been determined, carbonation must be carefully avoided, since a weight gain due to CO_2 would lead to serious error.

Apparatus

The apparatus used in the test includes the following: (*a*) standard autoclave (ASTM Method C 151-56),[5] (*b*) CO_2-free drying apparatus, and (*c*) crucible holder and stand for autoclave. The glass apparatus described in ASTM Method C 25 was not suitable for this method, so a CO_2-free drying apparatus, Fig. 1, of simple design was developed. The drying apparatus consisted of a small desiccator placed in an oven maintained at 120 C. The desiccator cover was provided with a hole fitted with a two-holed rubber stopper. Compressed air was passed through a train

[5] Method of Test for Autoclave Expansion of Portland Cement (C 151-56), 1956 Supplement to Book of ASTM Standards, Part 3, p. 55.

Fig. 3.—Crucible holder and platinum crucibles.

Fig. 2, consisting of a gas washing bottle containing concentrated sulfuric acid and a drying tower containing ascarite and magnesium perchlorate. The dry CO_2-free air was then passed through a small-bore soft copper tubing into the desiccator, through one of the holes in the rubber stopper. The desiccator was vented through the other hole. The copper tubing was coiled within the oven to provide flexibility and easy manipulation of the apparatus within the oven. The rate of air flow was 3 to 4 bubbles per second.

The crucible holder, Fig. 3, was made from a circular thin sheet of stainless steel $3\frac{1}{2}$ in. in diameter. Three holes $1\frac{1}{8}$ in. in diameter, to accommodate three crucibles, were cut in the sheet. The stand was made from a 5 in. outside diameter iron tripod, the legs of which were cut down to a height of 5 in. The stainless steel sheet was placed on the inside flange of the iron ring. Two small holes were drilled near the outer circumference of the iron ring, through which a stiff copper wire was fitted to serve as a handle.

Development of Test Procedure

Preliminary experiments were conducted to develop a simple, workable and reproducible method. With the exception of the CO_2-free apparatus, all equipment is likely to be available in a laboratory equipped to test cementitious materials.

It was established that the sample must be dried, before and after autoclaving, in a CO_2-free atmosphere. When placed in an ordinary electrically heated oven, the hydrated lime combined with CO_2 during prolonged drying. However, the sample attained constant weight in the CO_2-free drying apparatus in 2 hr and there was neither gain nor loss in weight when it was further heated therein overnight. These precautions, apparently prevented carbonation during drying. After autoclaving, when the sample contained considerably more moisture, a drying time of 3 hr was found to be satisfactory.

The standard autoclave of ASTM Method C 151[5] is used at 295 psi for cement testing. Although a lower pressure had been shown to be adequate (1), it was convenient in this study to autoclave at 295 psi for 1 hr (2). When an autoclaved and dried sample was replaced in the autoclave and treated at 295 psi for an additional 2 hr, no further weight gain resulted. Precautions had to be taken to prevent the hydrated lime from being carbonated during autoclaving. These precautions, which will be described below, seemed adequate.

It was found that a small sample was adequate and convenient. A covered

porcelain crucible occasionally filled up with water during autoclaving. When a platinum crucible was used, the lime sample appeared dry after autoclaving, and only a few droplets of condensed moisture adhered to the inside wall of the crucible. The crucible had to be shielded from moisture dripping from the top of the autoclave. An inverted nickel dish, about 40 mm in inside diameter and 10 mm deep, placed over the crucible served the purpose better than the regular platinum cover. A small stainless-steel spacer placed between the cover and the crucible assured easy passage of steam to the sample. A glass cover could not be used, since the glass reacted with steam and formed a scum which interfered with the test. It was deemed advisable to use only stainless steel or similar metals in contact with the platinum.

Method of Test

The following test procedure was developed as a result of the preliminary studies.[6]

[6] As this paper was being prepared for publication it was called to the author's attention that essentially the same method of test was suggested by V. S. Tadsen in an informal report to ASTM Committee C-7, on Lime, Feb. 5, 1957.

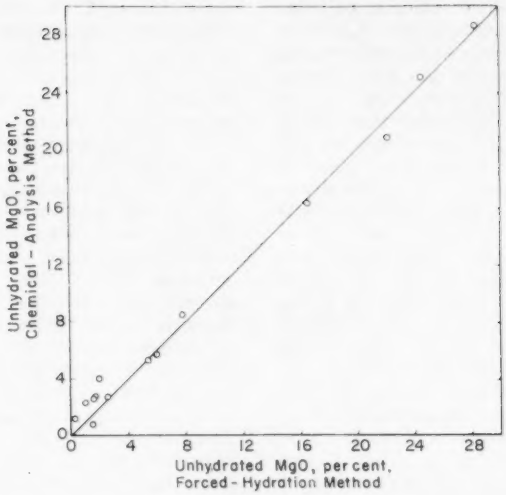

Fig. 4. Relation between percentage of unhydrated MgO values obtained by chemical analysis and by forced-hydration methods.

A 2 to 3-g sample was weighed on an analytical balance to 0.1 mg into a tared 25-ml platinum crucible. The sample was dried in the previously described CO_2- free apparatus for 2 hr, cooled in a desiccator containing ascarite and mag-

TABLE I.—CHEMICAL ANALYSIS AND CALCULATED PERCENTAGES OF UNHYDRATED MgO BY ASTM METHOD C 25[a] AND DETERMINATIONS OF UNHYDRATED MgO BY FORCED HYDRATION METHOD.

Lime Number	Free H_2O	Combined H_2O	CO_2	SO_3	SiO_2	R_2O_3	CaO	MgO	Total	Free MgO Calculated[a]	Free MgO, Forced Hydration[b]	Average Free MgO, Calculated = x	Average Free MgO, Forced Hydration = y	Difference, $\Delta = x - y$
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1...	...	16.00	2.15	0.13	2.35[c]		47.02	32.53	100.18	28.6	28.5 28.2	28.6	28.3	+0.3
2...	...	22.09	5.42	...	2.40[c]		41.11	28.86	99.88	4.0	2.0 2.0	4.0	2.0	+2.0
3...	0.38	15.51	18.66	...	1.36	0.55	37.18	26.31	99.95	1.2	0.3 0.3	1.2	0.3	+0.9
4...	0.16	24.75	1.96	...	1.45	0.61	41.96	29.36	100.25	2.3	1.0 1.1	2.3	1.0	+1.3
5...	0.22	24.56	2.33	...	0.16	0.20	42.69	29.03	99.19	2.6	1.6 1.6	2.6	1.6	+1.0
6...	0.23	23.67	4.02	...	0.22	0.15	41.89	29.24	99.42	2.7	2.6 2.6	2.7	2.6	+0.1
7...	0.29	24.54	3.75	...	0.14	0.29	41.65	29.22	99.88	0.8	1.5 1.5	0.8	1.5	−0.7
8...	0.26	23.22	3.53	...	0.27	0.19	42.55	29.93	99.95	5.3	5.4 5.4	5.3	5.4	−0.1
9...	0.17	17.50	0.63	0.28	1.64	1.52	46.30	32.08	100.12	25.5	24.5	25.1	24.5	+0 6
		17.52	0.61		1.66	1.43	46.17	31.33	99.17	24.6	24.4			
10...	0.32	19.34	0.77	0.01	0.21	0.50	48.01	29.64	98.80	20.2	22.2	20.8	22.2	−1.4
		19.46	0.78		0.19	0.55	47.71	31.32	100.34	21.4	22.2			
11...	0.33	17.01	7.72	0.14	0.51	0.81	44.73	29.05	100.30	16.0	16.8	16.3	16.6	−0.3
		16.71			0.39	1.08	44.78	29.00	100.15	16.7	16.4			
12...	0.24	22.33	3.25	0.21	0.16	0.35	43.01	30.35	99.90	8.2	7.8	8.5	7.8	+0.7
		22.26			0.20	0.49	43.16	30.61	100.42	8.8	7.9			
13...	0.18	24.29	1.32	0.28	0 13	0.49	43.08	30.34	100.11	5.6	5.9	5.7	6.0	−0.3
		24.19			0.07	0.68	43.04	30.32	100.08	5.8	6.0			
14...	0.31	24.36	2.22	0.04	1.22	0.90	41.87	28.80	99.72	2.3	1.7	2.8	1.7	+1.1
		24.18			1.20	0.88		29.32	100.02	3.3	1.7			

[a] The chemical analyses and calculated unhydrated oxides were obtained, essentially according to ASTM C 25-47, by two different chemists; samples 1 to 8 by W. F. Clarke, 9 to 14 by H. A. Berman.

[b] Unhydrated MgO was determined, in duplicate, on different days by one operator. Samples were autoclaved 1 hr at 295 psi in standard autoclave (ASTM Method C 151-54).

[c] Represents combined value of SiO_2 and R_2O_3.

nesium perchlorate and weighed. The autoclave, containing the customary amount of water, was heated and the water was brought to a boil. Boiling was continued for 3 to 4 min to dispel the dissolved CO_2 in the water and to displace the CO_2-air mixture in the autoclave by steam. The platinum crucible was placed on the stand previously described, and the crucible was loosely covered with the inverted nickel dish. The stand, together with the crucible, was lowered into the steam filled autoclave, and the lid was immediately placed on the autoclave and fastened. The cold lid reduced the temperature within the autoclave, and in order to prevent outside air from being drawn into the autoclave, the vent valve was kept closed until the thermometer in the well indicated 100 C and the pressure gage reading was about 10 psi. The autoclave was then vented and the valve again closed. The autoclave was heated to 295 psi, maintained at this pressure for 1 hr, and then cooled until the temperature dropped below 100 C. The autoclave was opened and the crucible transferred immediately to the CO_2-free drying apparatus described above, dried 3 hr, cooled and weighed. The increase in weight, which was the difference between the oven-dry weights before and after autoclaving, was assumed to be a gain in H_2O, and was multiplied by the conversion factor 2.238 to obtain the weight of free MgO present. The weight of free MgO times 100 was divided by the original weight of the test sample to obtain the percentage of free MgO.

Results and Discussion

After the procedure and methods of test were standardized, duplicate tests were made by the forced-hydration method, on different days, on 14 selected hydrated dolomitic lime samples, including both regularly hydrated (N) and highly hydrated (S) limes. Comparative data were also obtained on the unhydrated MgO content of the same limes by the standard chemical analysis method. The results are shown in Table I and Fig. 4.

Results of the Two Methods of Test

Table I, columns 2 to 10, lists the percentage composition of the limes, while column 11 lists the percentage unhydrated MgO calculated from chemical analysis. The values for samples 1 to 8 are the results of single determinations by W. F. Clarke; the values for samples 9 to 14 are the results of duplicate determinations by H. A. Berman. Column 12 of Table I lists the duplicate results of unhydrated MgO determinations by the forced-hydration method. The results of these duplicate tests show good reproducibility, with a standard deviation of 0.10. By comparison, the standard deviation for the six duplicate values for unhydrated MgO for samples 9 to 14, in column 11, is 0.51. The standard deviations of 0.51 and 0.10 for the unhydrated MgO values obtained by individual operators by the chemical analysis and the forced-hydration methods, respectively, indicate that the latter is considerably more precise.

The respective unhydrated MgO values obtained by the two methods, columns 11 and 12, are at variance. The range of difference is from +2.0 to −1.4 per cent. These differences are not necessarily excessive, considering that the duplicate determinations by the analytical method for samples 9, 10, and 14 differed among themselves by approximately 1 per cent. In the majority of cases the forced-hydration method resulted in lower values, the average difference being 0.37 per cent.

In order to test the significance of the difference of the results obtained by the two methods, a t-test[7] was made. For this purpose the respective average unhydrated MgO values of the individual limes obtained by the chemical analysis and forced-hydration method are listed in columns 13 and 14, and are respectively identified as $\bar{x}$ and $\bar{y}$ values. The difference, identified as Δ, is given in column 15. The single chemical analysis determinations for lime samples 1 to 8 are considered to be the average of two determinations for this statistical test. The value for t, using all the data in column 15, was 1.60. The critical value of t at the 95 per cent level for 14 samples is 2.16. By this statistical test, then, there is no significant difference between the values of the unhydrated MgO obtained by the two methods.

Figure 4 shows the relation between the average unhydrated MgO values obtained by the forced-hydration method and the values obtained by the analytical method. The line shown represents equality of values of the two methods. The plotted values show good correlation. The deviations from equality are random and do not increase with increased total unhydrated MgO.

Reliability of the New Test Method

The assumptions made in the standard ASTM method for calculating free MgO may not be in strict accord with actual composition, and it is so stated in the closing note of ASTM Method C 25. The principal uncertainties concerning the above assumption are (*a*) whether the CaO in hydrated dolomitic lime, as received, is completely hydrated, and (*b*) whether the R_2O_3 and SiO_2 have combined with the lime during the burning process to form silicates and aluminates. (In limes, Al_2O_3 is usually the main constituent of R_2O_3.) No provision is made in ASTM Method C 25 in the calculation for any residual CaO, nor is there any direction as to how to handle the R_2O_3 and SiO_2. It is generally reasoned, however, that since the residual CaO, the R_2O_3 and the SiO_2 are usually small, the error introduced can be overlooked.

It is of interest to analyze and compare the errors that might be introduced in the two methods of test by the above assumptions. Let us imagine a sample of hydrated dolomitic lime, which contains 10 moles of CaO, 10 moles of MgO and 15 moles of H_2O (combined). The chemical analysis method assumes that

$$10\,CaO + 10MgO + 15H_2O = 10(CaO \cdot H_2O) + 5(MgO \cdot H_2O) + 5MgO$$

and the 5 moles of MgO are reported as a percentage of the total. Should the sample actually contain 1 mole of free CaO, then in reality we would have

$$10CaO + 10MgO + 15H_2O = 9(CaOH \cdot {}_2O) + CaO + 6(MgO \cdot H_2O) + 4MgO$$

The total free oxides would be 4MgO + CaO, and since CaO has a greater molecular weight than MgO, the percentage of MgO reported would be less than that of the total percentage of free oxides actually present. The identical error would exist in the forced-hydration method. The gain in weight would amount to 5 moles of H_2O and it would be assumed that the lime contained 5 MgO instead of 4MgO + CaO. The error involved is small, however. For each per cent of free CaO that the lime may contain, 0.72 per cent of free MgO would be assumed instead.

Should the SiO_2 and Al_2O_3, normally present in dolomitic lime, react with CaO during the calcining to form silicates and aluminates, the average calcining temperature and the abundance of the CaO would be conducive to the production of tricalcium aluminate

[7] The value of t was calculated by the equation

$$t = \frac{\frac{\Sigma\Delta_i}{14}\sqrt{14}}{\sqrt{\frac{\Sigma\Delta_i^2 - \frac{(\Sigma\Delta_i)^2}{14}}{14-1}}}$$

where $\Delta_i = \bar{x}_i - \bar{y}_i$, and $\bar{x}_i$ and $\bar{y}_i$ are the average values obtained for the ith sample by the two methods.

(C_3A) and dicalcium silicate (C_2S) (3). Let us consider the C_3A first. During the normal process of hydration at the plant, the C_3A would readily hydrate and form $C_3A{\cdot}6H_2O$ (4). Let us again consider the hypothetical lime sample mentioned above, and assume that it contains additionally 1 mole of Al_2O_3. The chemical analysis method assumes that

$$10CaO + 10MgO + Al_2O_3 + 15H_2O = 10(CaO{\cdot}H_2O) + 5(MgO{\cdot}H_2O) + Al_2O_3 + 5MgO$$

whereas the sample actually contains

$$7(CaO{\cdot}H_2O) + 3CaO{\cdot}Al_2O_3{\cdot}6H_2O + 2(MgO{\cdot}H_2O) + 8MgO$$

The analyst would, therefore, report 3 moles less free MgO than actually present. In the forced-hydration method, the hydrated C_3A would remain unchanged in the autoclave, all the free MgO would be hydrated with consequent gain in weight, and the method would yield correct result. Let us take lime No. 4 as a practical example. It contained 0.61 per cent R_2O_3, an average amount. If we assume that all of the R_2O_3 was Al_2O_3, then 0.72 per cent less MgO than actually present was reported by the chemical analysis method.

If our hypothetical sample contains 1 mole of SiO_2 combined with CaO as C_2S, it is fair to assume that it did not hydrate in the plant hydrator, since C_2S does not hydrate readily (5). The chemical analysis method would assume that

$$10CaO + 10MgO + SiO_2 + 15H_2O = 10(CaO{\cdot}H_2O) + 5(MgO{\cdot}H_2O) + SiO_2 + 5MgO$$

However, we would have

$$8(CaO{\cdot}H_2O) + 2CaO{\cdot}SiO_2 + 7(MgO{\cdot}H_2O) + 3MgO$$

and the 5 MgO reported would be 2 moles more than the moles actually present.

It is uncertain whether the forced-hydration procedure will completely hydrate the C_2S. If there is no hydration of C_2S, the forced-hydration method will yield correct results. If the C_2S is completely hydrated to C_2S monohydrate (5), then one additional mole of H_2O will have been gained during autoclaving. This will result in reporting 4 moles of free MgO instead of 3, 1 mole more than the correct number. In the case of lime No. 4, which contained 1.45 per cent SiO_2, 1.93 per cent more free MgO than the true value would be reported by the chemical analysis method (column 11). The forced-hydration method (column 12) would yield 0.97 per cent more free MgO than the true value.

The combined theoretical error in reporting free MgO, due to the combination of both the SiO_2 and the Al_2O_3 with CaO, in lime No. 4 amounts to 1.93 − 0.72 = 1.21 per cent for the chemical analysis method and 0.97 per cent for the forced-hydration method. The combined theoretical errors were calculated for all the 12 limes for which SiO_2 and R_2O_3 data are given in Table I. The average theoretical error for the chemical analysis method came to +0.15 per cent and for the forced-hydration method to +0.41 per cent. It would seem that the theoretical errors in the forced-hydration method are not substantially different from the combined theoretical errors in the chemical analysis method.

Consideration for Specification Requirement

There is no significant difference between the free MgO values obtained by the two methods. The new method for free MgO determination in dolomitic lime hydrate is much simpler and considerably faster than the standard method. Good reproducible results can be obtained in one working day. It is suggested, therefore, that the new method for free MgO determination be considered for a revision of Federal Specification SS-L-351 and be incorporated as optional in ASTM Method C 25.[4]

Acknowledgment:

The author expresses thanks to W. F. Clarke and H. A. Berman for the chemical analysis of the limes and to E. S. Newman for his statistical treatment of the data.

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A Study of the Low-Temperature Brittleness Testing of Polyethylene

By E. A. W. HOFF and S. TURNER

Low-temperature brittleness tests such as ASTM D746 do not give unique values for polyethylene and depend markedly on specimen preparation. If brittle test results are to be meaningful and reproducible a more stringent specification covering specimen preparation and conditioning is needed.

As is well known from experience, a thermoplastic polymeric material usually becomes prone to fracture or cracking as the temperature is lowered. Various methods of characterizing the temperature or temperature region at which this occurs have been proposed; many are simple pass-or-fail tests executed by applying some sudden, but otherwise arbitrary, deformation to find the temperature at and below which fracture ensues. One such method was standardized in 1944 by the American Society for Testing Materials (D 746 – 44 T)[1]; later Smith and Dienes (1)[2] described a new apparatus and drew attention to the need for a statistical approach to the evaluation of test results in certain circumstances; this work led to the revisions incorporated in ASTM Method D 746 – 55 T.[3] A similar development took place in the laboratories of Imperial Chemical Industries Ltd., the objective being to get a quantitative measure of the low-temperature brittle point of polyethylene. The apparatus evolved differs in various respects, but not in principle, from the ASTM version.

Recently a detailed study has been made in these laboratories of a number of factors which appeared likely to affect the test results, and their reproducibility, say, at different times and in different laboratories. The detailed construction and mode of operation of the Imperial Chemical Industries (ICI) brittleness tester used in this work is described in a companion paper in which detailed comments on the evaluation of results will also be found. The study reported here is mainly concerned with polyethylene as the test material; comparison with other materials showed that polyethylene requires a greater attention to detail of test procedure than hitherto specified. As this was found to apply equally to the ASTM procedure, there appeared to be an added incentive to make our findings known outside our own laboratories.

The first part of this paper summarizes our main results and finishes with recommendations deemed useful to make the testing of polyethylene more reproducible; a modified test, using a notched specimen, is also proposed. Only the immediately relevant information on experimental technique is given here; greater detail can be found in the companion paper. The second part of this paper engages in more speculative considerations in an attempt to present a unified view of the behavior of polymers, in particular polyethylene, in a low-temperature brittleness test.

Experimental Technique

The apparatus used can take 160 specimens and so test 20 specimens at each of eight different temperatures on a single charge; it had been found (2) that this scale of testing is necessary to obtain answers of the precision sometimes desired in investigational work; one such determination can be done in about 3 hr. The specimen size was 2 cm long, 0.25 cm wide, and 0.16 cm thick; the thickness tolerance accepted, 0.062 to 0.068 in., was somewhat smaller than in ASTM Method D 746 – 55 T.[3] Air thermostating was used and the deformation applied to the specimens consisted in bending them through 90 deg around a mandrel 0.8 cm in diameter in 0.25 sec.

For evaluation, the probit method was used, that is, the percentage (of 20 specimens) fractured was plotted against temperature on arithmetic probability paper and a straight line drawn through the points. From this graph the brittleness temperature, T_{50}, at which 50 per cent of the specimens fracture was read off as well as the standard deviation, σ, of the distribution, which is the tem-

E. A. W. HOFF, currently in charge of the Physical Division of the Research Department, Imperial Chemical Industries Limited, Plastics Division, has been engaged for the past eleven years in polymer research and in the testing and measurement of physical properties of polymers.

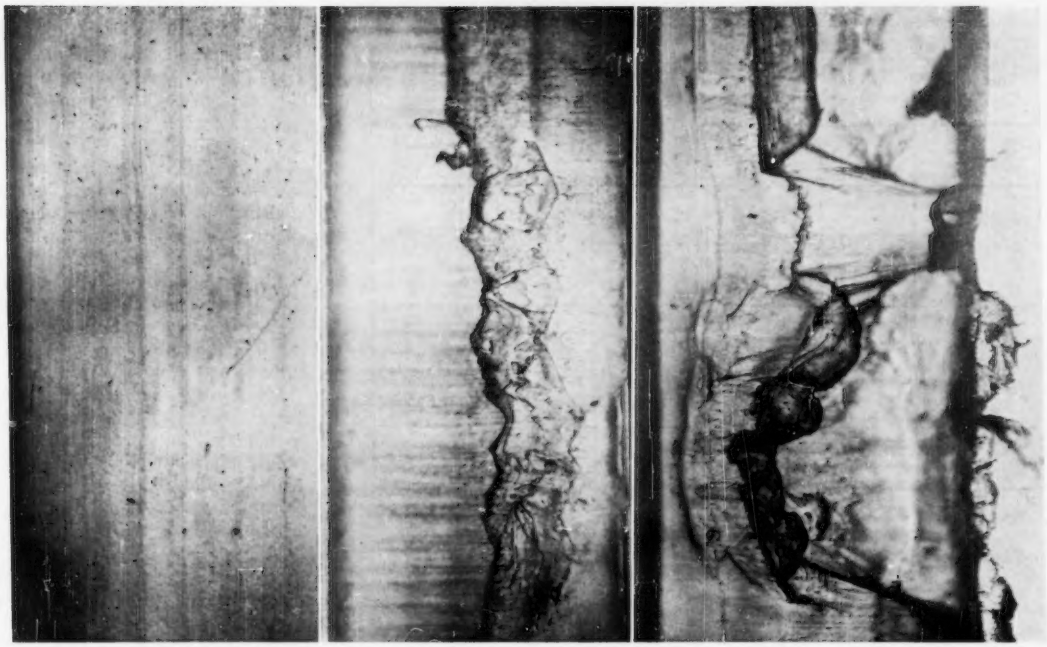
S. TURNER has been engaged for the past five years on research into the mechanical properties of viscoelastic materials, polyethylene in particular. During part of this time he has been concerned with problems associated with the standardization of testing methods.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to ASTM Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Tentative Method of Test for Brittleness Temperature of Plastics and Elastomers by Impact (D 746 – 44 T), 1944 Book of ASTM Standards, Part 3, p. 1605.

[2] The boldface numbers in parentheses refer to the list of references appended to this paper.

[3] Tentative Method of Test for Brittleness Temperature of Plastics and Elastomers by Impact (D 746 – 55 T), 1955 Book of ASTM Standards, Part 6, p. 148.



(a) Razor-cut ↓ (b) ←— Guillotine-cut (c) —→ Die-cut

The arrows indicate the direction of travel of the cutting edge.

Fig. 1.—Enlarged photographs of specimen edges (original thickness 0.16 cm).

perature difference between 15.9 and 50 per cent fracture. To obtain a check on this graphical method and to increase reliability in cases of bad experimental scatter, the provisional straight line, drawn by eye while giving most weight to points lying between 20 and 80 per cent fracture, was in many instances recalculated using the method of weighted probits (2). It turned out that the graphical method gave remarkably good estimates of T_{50}; in five cases where there was considerable scatter of points, the computation changed the value of T_{50} once by 1.6 C, in the other four cases by 0.3 C or less. The standard deviation σ, however, was much more sensitive to estimation error, differences of up to 40 per cent having been encountered between graphical and computed estimates.

Most of the work described here was carried out on the "Alkathene" brand of polyethylene, having melt flow indices (MFI) of 2, or 7, or 20 and densities of 0.91 to 0.92 g per ml. Each polymer batch was homogenized by milling, chipped, molded into sheets, and cut into specimens; these were then usually annealed in boiling water for 10 min, unless the effect of annealing itself was to be studied; it was already known that annealing could raise T_{50} considerably.

The results are presented in four groups, according to the specific lines of investigation pursued.

Effects of Specimen Preparation, Carbon Black Content, and Melt Flow Index on the T_{50} of Polyethylene

Specimens were cut in three different ways from the sheets, giving three differing degrees of damage to the cut sides, as illustrated in Fig. 1; the arrows there indicate the direction of travel of the cutting edges. Razor-cut specimens were made by steadily drawing a sharp razor blade parallel to the plane of the sheet; the guillotine cutter pressed an inclined knife edge through the sheet at right angles to its plane; the die-cutter also worked at right angles to the sheet plane, but stamped out the specimen by a shearing action.

Figure 1 shows that in guillotine cutting, the leading edge of the specimen (made by the entering knife) was distinctly more damaged than the final edge; this remained true even for a very sharp guillotine cutter. Since during a test only one of the leading or final edges is put in tension, one might expect an effect on the test result, and this was in fact found, as shown in Fig. 2 relating to "Alkathene" of melt flow index (MFI) = 20. The full points refer to specimens all put in the tester so as to have their final (good) edge in tension, giving a T_{50} of −49.5 C. The crosses refer to specimens tested on their leading (poor) edges, T_{50} = −34.5 C, and the circles show the large scatter resulting from putting specimens randomly into the tester. For definiteness, all subsequent tests on guillotine cut specimens were done "on their worse edge," giving the higher brittleness temperature. Subsidiary tests showed some variations of the T_{50} obtained with different guillotine cutters, and small day-to-day variations with the same cutter; the latter were apparently not associated with a systematically changing sharpness of the knife, since T_{50} moved either way randomly.

Figure 3 illustrates, on the same batch of "Alkathene," the wide range of brittle temperatures that can arise when different methods of specimen preparation are used. Razor cutting produces the lowest and die cutting the highest brittle temperatures; apparently the increased mangling of specimen edges is equivalent to some kind of notch effect. A minor difference between "leading" and "final" specimen edges was also found for die cutting, but the effect is less well marked than with the guillotine. Other batches of "Alkathene" (MFI = 20) gave not quite as low a T_{50}

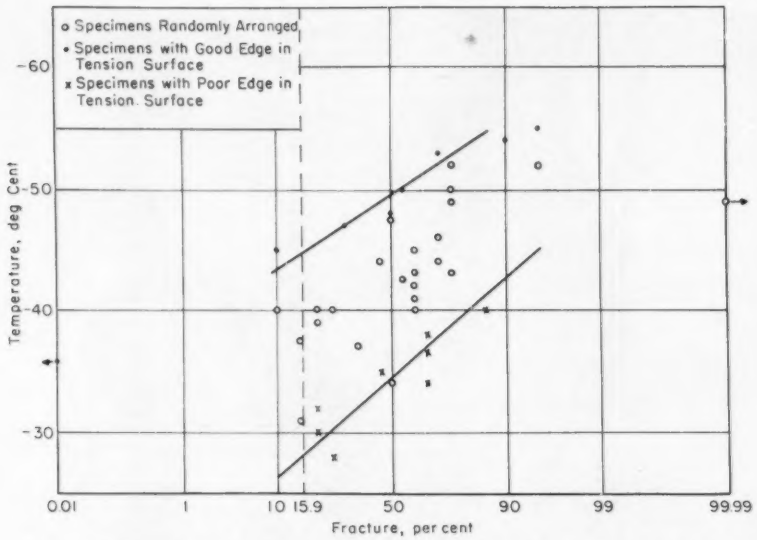


Fig. 2.—Distribution of fractures as a function of temperature, "Alkathene" (MFI 20) guillotine-cut specimens.

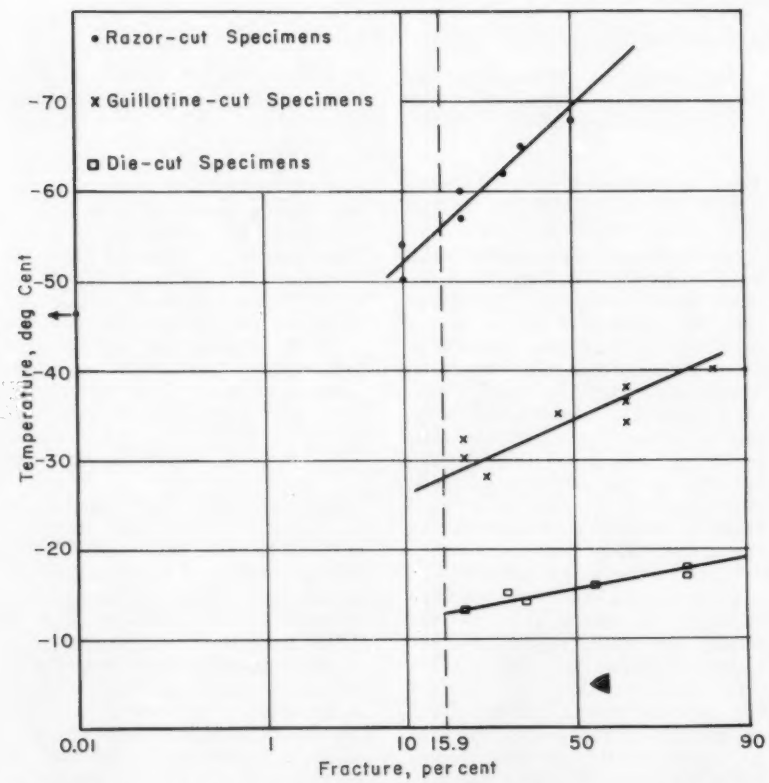


Fig. 3.—Distribution of fractures for various methods of specimen preparation, "Alkathene" (MFI 20).

with razor cutting as the one illustrated in Fig. 3, but always much lower than with other methods of specimen preparation. Table I summarizes the results for "Alkathene" of three different melt flow indices; for all three the brittle temperature, T_{50}, is the lower, and the standard deviation, σ, the larger, the less the specimen has been damaged in preparation. The brittle temperature also falls with decreasing melt flow index, that is, as the material generally becomes tougher. To obviate between sheet variations, all specimens of the same MFI were made from the same sheet and randomly assigned to their three respective tests.

A test series similar to that given in Table I was carried out on "Alkathene" containing 2.5 per cent carbon black ("Kosmink"), incorporated by milling. Table II shows that the carbon black slightly raises the T_{50} of guillotined and die-cut specimens (with one exception in Table II), and appreciably raises the T_{50} of razor-cut specimens, while σ is hardly affected. Thus there may be an abrasive or notching effect of carbon particles during specimen cutting, but the conclusion is not definite.

Other tests showed that the effect of specimen preparation on T_{50} is not confined to "Alkathene," but occurs to the same extent in all polyethylenes examined, which included five materials of American and European origin. Furthermore, the same sensitivity of the result to specimen preparation obtains if the test is carried out according to ASTM Method D 746 – 55 T[3], using the ASTM tester. In this test slightly higher T_{50} values are obtained, as one might expect since the manner and speed of deformation are more severe. Table III briefly illustrates the point: the other points made in this paragraph are not supported by the detailed data so as not to encumber this paper too much.

ASTM Method D 746 – 55 T[3] contains no safeguard against effects of specimen preparation; the results just presented suggest a need for a relevant specification and for a warning against comparing results obtained without the indicated precautions.

The Effect of Deliberate Notching on T_{50}

The results of the preceding section suggested that notches may have been inadvertently introduced into specimens, depending on the cutting method, leading to a rise in brittle temperature as a consequence of stress concentrations at the bottom of fine fissures subsequently tensioned during testing. This thought led to the investigation of "notches" deliberately applied, for ex-

TABLE I.—EFFECT OF SPECIMEN CUTTING METHOD AND MELT FLOW INDEX ON THE BRITTLENESS TEMPERATURE AND ITS STANDARD DEVIATION OF "ALKATHENE."

T_{50} and σ (in parentheses) in deg Cent determined on ICI tester

Melt Flow Index	Razor Cut	Guillotined	Die Cut
20	−69.5 (13.5)	−34.5 (6.5)	−15.5 (3.0)
7	Below −70	−50.0 (8.0)	−28.0 (3.5)
2	Below −70	Below −70	−35.0 (2.5)[a]

[a] Based on 5 temperatures only, σ probably inaccurate.

TABLE II.—EFFECT OF SPECIMEN CUTTING METHOD AND MELT FLOW INDEX ON THE BRITTLE TEMPERATURE AND ITS STANDARD DEVIATION OF "ALKATHENE" LOADED WITH 2.5 PER CENT CARBON BLACK.

T_{50} and σ (in parentheses) in deg Cent determined on ICI tester

Melt Flow Index	Razor Cut	Guillotined	Die Cut
20	−46.0 (11.0)	−31.5 (6.0)	−19.0 (1.5)
7	−71 (16)[a]	−46.0 (8.0)	−24.0 (2.5)
2	...	−71 (10)	−27.5 (6.5)

[a] Data unsymmetrical about T_{50}, σ probably inaccurate.

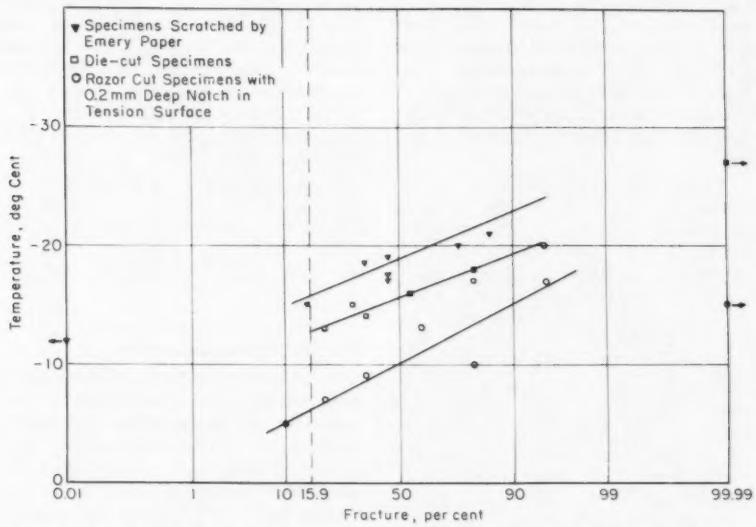


Fig. 4.—Distribution of fractures for various methods of notching, "Alkathene" (MFI 20).

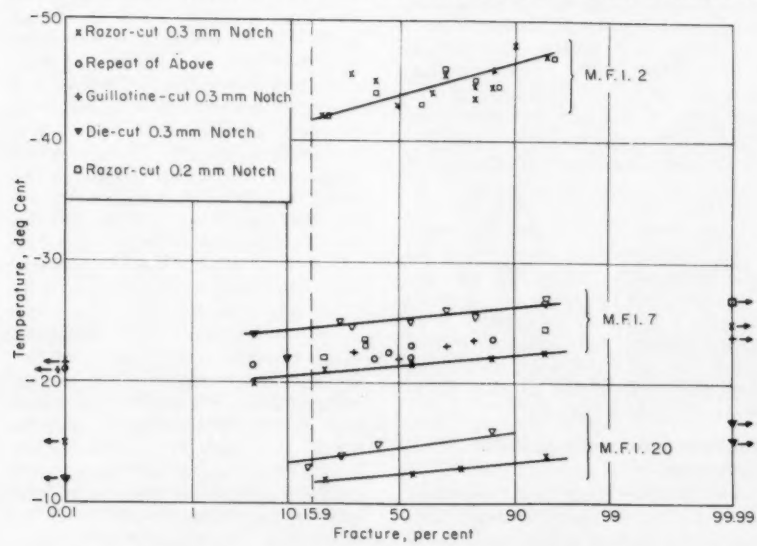


Fig. 5.—Distribution of fractures for "Alkathene" specimens notched on side.

TABLE III.—EFFECT OF SPECIMEN CUTTING METHOD AND MELT FLOW INDEX ON THE BRITTLENESS TEMPERATURE OF "ALKATHENE" TESTED ACCORDING TO ASTM METHOD D 746 – 55 T[3].

T_{50} and σ (in parentheses) in deg Cent determined on the ASTM tester

Melt Flow Index	Razor Cut	Guillotined
20	−62	−25.0 (4.5)
7	~−74	−46.5 (5.0)

ample, in a random fashion by rubbing specimen surfaces in various ways with emery paper, or by cutting notches with a razor blade into the side face or top face (subsequently tensioned) of the specimen. The specimens were always annealed after notching and before testing.

The general result was that any such notches raised T_{50} as expected; the random scratching with emery was not well reproducible. A razor cut in the top face of the specimen had a very severe effect, but again there was bad reproducibility, probably because the notch depth was very critical; also, over a wide temperature range, specimens frequently fractured only part of the way through, thus requiring an arbitrary decision whether a given specimen had fractured or not. Razor-cut notches in the side face of the specimen, however, appeared suitable as a basis for a test on deliberately notched specimens. All the razor notches were applied to the specimen midway between its ends by pressing in the razor, held in a notch depth controlling jig, without cutting action; in the tester the notches came to lie just outside the clamped region.

Figure 4 shows some of the results obtained for the same material as used for Figs. 2 and 3. A 0.2-mm deep notch in the tension face of a razor cut specimen has an effect even more severe than die cutting; the effect of emery rubbing is less severe.

Figure 5 shows the results obtained with materials of the three MFI's 2, 7, and 20, with the specimens prepared in various ways, but all notched in the side face. Although the notch depth had usually increased after testing, there was never any difficulty in deciding whether a specimen had fractured or not. The notch depth is not critical at 0.2 or 0.3 mm, whereas the severity of such a notch appears practically to over-ride the previously discussed effects arising from specimen cutting methods. A further practical advantage is the low standard deviation, σ, of the distribution of fractures associated with notching. For convenient comparison, Table IV has been compiled which gives typical values of T_{50} and σ resulting from the notch tests. No results which disagree with

this general pattern of behavior were obtained.

The Effect of Annealing Conditions on the Brittle Temperatures of "Alkathene"

The effect of annealing is brought up here because ASTM Method D 746 –55 T[3] does not include a relevant reference. The standard practice for many years within these laboratories has been to anneal by immersion in boiling water for 10 min, followed by rapid cooling in air, before the low-temperature brittle test; this produces an appreciable rise of T_{50} absolute values depending, of course, on melt flow index. Immersion for longer than 10 min in boiling water or annealing at 105 C produce no further change. However, the cooling rate is important; thus, guillotine-cut specimens of "Alkathene" (MFI = 7) give $T_{50} = -50$ C after rapid cooling from 100 C in air and $T_{50} = -36.5$ C when cooled at 0.5 C per min, approximately.

The Brittle Testing of Materials other than Polyethylenes

Similar tests as described have shown that polytetrafluoroethylene, that is, both brands "Teflon" and "Fluon," possess a T_{50} insensitive to the way in which the specimens have been cut. The σ of these materials is large, as in tough polyethylenes. Poly(vinyl chloride)compositions containing various proportions of plasticizer have a very sharp distribution of fractures, with a $\sigma = 1.0$ C only, and again are insensitive to the method of specimen preparation.

Summarizing and Concluding Remarks

The results of the experiments described above show how the brittleness temperature of polyethylene depends upon the melt flow index, upon the method of specimen preparation, and upon the annealing cycle to which the specimens are subjected prior to testing. Different types of cutting tool produce different values of T_{50}, and there is a distribution of percentage fracture as a function of temperature which becomes wider for the more carefully prepared specimens and for the materials with lower melt flow index. Some variability exists from day to day for the same cutter; the die-cutter is particularly susceptible to gradual deterioration during use. The die-cutter produces a specimen which is badly torn at the edges and, when tested, the specimens break at random points along the length, whereas specimens prepared more carefully nearly always break near the point of clamping. It is reasonable to assume that in the former case the point of fracture is at the site of a particularly severe notch accidentally produced by the tool; in the latter case the edge of the clamp influences the local stress distribution. Since the edge of the clamp is rounded, no real notching is occurring at this point, and the maximum skin strain near the clamp (9 per cent in the ICI tester) is the dominant factor influencing fracture. It can be seen in Fig. 2, that, even if a particular cutter is used, uniformity of results will follow only if the specimens are arranged in a particular manner in the apparatus since the front and back surfaces of the specimen are damaged to different extents by the cutter and behave differently under test.

TABLE IV.—EFFECT OF NOTCHING AND MELT FLOW INDEX ON THE BRITTLE TEMPERATURE AND ITS STANDARD DEVIATION OF "ALKATHENE."

T_{50} and σ (in parentheses) in deg Cent determined on the ICI tester

Specimen Preparation	Nature of Notch	Melt Flow Index		
		20	7	2
Die cut	none	−15.5 (3.0)	−28.0 (3.5)	−35.0 (2.5)
Razor cut	Emery	−19.0 (3.5)	...	...
Razor cut	0.2 mm, front	−10.0 (4.0)	...	...
Razor cut	0.2 mm, side	...	−23.0 (1.0)	−44.0 (2.0)
Razor cut	0.3 mm, side	−12.5 (1.0)	−21.5 (1.0)	−44.0 (2.0)
Die cut	0.3 mm, side	−14.5 (1.0)	−25.0 (1.0)	...
Guillotined	0.3 mm, side	...	−22.5 (1.0)	...

One can thus recommend that a specification for the brittle testing of polyethylene should prescribe an annealing treatment and a controlled method of specimen preparation, bearing in mind that a test result for polyethylene is not necessarily in every way comparable to that for a material of a different nature, because the property measured may not be exactly the same in the two cases. The points raised become important if comparisons are to be made between laboratories or over long periods of time, for example, in the evaluation of exposure trials. An even furthergoing modification of the test would prescribe a deliberate notch in the specimen side, with the advantage of thus eliminating a number of accidental factors, of moving the results for tougher grades into an experimentally more convenient temperature range, and of benefiting from the reduced standard deviation associated with this procedure. A further factor is that the material is then tested under conditions similar to that of accidental surface damage of products in service; this would facilitate the assessment of serviceability by delimiting the safe temperature range. The preparation of notched specimens can be mechanized; a relatively inexpensive automatic machine has been constructed which cuts and notches specimens from 2-cm wide strip of the required thickness at the rate of 1 per sec.

Fundamental Aspects of Brittle Testing

This section deals with somewhat more speculative aspects of brittle testing, arising because an intelligent use of the test and interpretation of its result requires at least a partial appreciation and understanding of underlying physical phenomena. It cannot be claimed that this point has been cleared up; only a first step in what is assumed to be the right direction will be considered. As a starting point it will be assumed that the standard deviation of the distribution of fractures in a brittle test can be either small or large; that the brittle temperature is also one at which the polymer stiffens and thus is related to a transition, either of the rubber-glass type or a cognate one; that the fracture phenomenon may be complicated by "notch-sensitivity," a concept referring to a real phenomenon but which is nevertheless very difficult to reduce or relate to simpler physical properties.

The Distribution of Fractures

Two views may be taken to explain why not all specimens fracture at exactly the same temperature. In the first picture each specimen possesses a definite worst fault in the locality of stress maximum during testing; then the distribution of fractures arises from a distribution of faults and is a property of the population of specimens, not of an individual specimen which always has the fixed brittle temperature characteristic of its worst fault. Further, if a batch of specimens is tested at a temperature such that some of them break, no further fractures should occur on re-testing at the same temperature. The second view assigns the whole distribution function of fractures to each specimen; the distribution then arises from the distribution of thermal energy in polymer chain segments or similar small aggregates; during the test, competition exists between relaxation and the rise of strain energy as the specimen is deformed; whether fracture is initiated or not then depends on the local level of thermal energy. This or a similar view would place the brittle temperature near the temperature region of a mechanical dispersion (for example a rubber-glass or similar transition) in which relaxation rates are temperature sensitive. If this view holds, then repeated re-testing of survivors at the same temperature

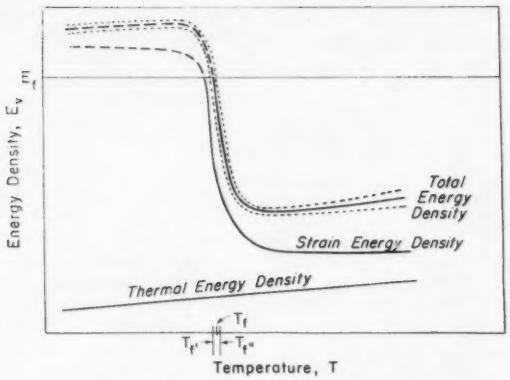


Fig. 6.—Maximum energy density developed during the test as a function of temperature.

The steeper the slope of the total energy density curve where it intersects the critical energy density line (E_f) the narrower the distribution of fracture. The dotted lines indicate the standard deviation of the total energy density. For all energies greater than E_f the energy density curves cannot represent a real situation.

should give a constant proportion of fractures.

Practical work to test these views has remained somewhat inconclusive. An added difficulty is that fatigue effects when retesting cannot with certainty be excluded or assessed. A single test carried out some years ago was based on 400 polyethylene specimens tested according to ASTM procedure at a temperature giving 80 per cent mortality; retesting the survivors did not significantly change the mortality rate. A more comprehensive test was more recently done with the ICI tester on a large number of specimens of "Alkathene" (MFI = 7), all cut from the same sheet and randomly grouped into batches. The first batch of 160 specimens was used to determine T_{50} (−42 C) and σ (7.5 C). Two further batches, A and B, each of 160 specimens, were then tested at −40 C; the expected mortality was about 39 per cent, but 30.6 per cent was found; the specimens were left in their clamps, allowed 90 min recovery at room temperature (they remained a little bent) and retested at −40 C. Batch A now gave 13.5 per cent and batch B 15.3 per cent mortality; the 96 survivors of batch B were now allowed to recover at room temperature for several days after removal from the clamp, whereby they straightened out almost completely, carefully reclamped in the same way as they had been before and retested, giving T_{50} = −52 C, σ = 8.5 C. The survivors of batch A, after a similar recovery at room temperature, but without unclamping, were tested a third time at −40 C, giving 18.8 per cent mortality; this does not significantly differ from the second result. The remaining survivors of batch A gave a T_{50} of −45 C, σ very high, but unreliable because of the small specimen number. Finally the remaining survivors of A and B, 79 in number, were pooled and tested at −40 C, giving 31.6 per cent mortality. To be conclusive, experiments like the one described have obviously to be based on a very much larger specimen number than has been done. The apparent strength increase on retesting may in part be due to unrecovered bending, in part to elimination of specimens with fixed faults according to the first view explained above; fatigue effects do not appear to be serious. The second view, that is, that the distribution of fractures is a property of each specimen, appears to be sufficiently true to serve as a basis for further argument, bearing in mind that a disturbing factor arising from fixed faults may exist.

A Proposed Mechanism of Fracture in Low-Temperature Brittle Testing

Figure 6 is a hypothetical graph to illustrate the assumed energy conditions in a specimen bent around a mandrel during the brittle test. The average thermal energy per unit volume is represented by a straight line, rising with temperature. The strain energy per unit volume is represented by a sigmoid curve, representing the variation of the relaxation modulus with temperature, which is an appropriate energy measure at constant strain; since only the (known) shape of the curve matters, discussion of the numerical values appropriate to testing rate and strain level is not necessary. The third, uppermost, curve represents the sum of thermal and strain energy and is accompanied by dashed curves to indicate the energy fluctuations arising from thermal fluctuations in a small volume element critical for the onset of fracture. If we further assume a critical total energy density E_f at which fracture occurs, then the intersection of the horizontal line labelled E_f with the total energy density curve represents the temperature region of distributed fractures, indicated on the temperature axis by $T_f \simeq T_{50}$ and the range $T_{f'}$ to $T_{f''}$. Since energies exceeding E_f cannot be realized in a test, the corresponding curve branches have been drawn in dashes. E_f may be temperature dependent, but nothing is known about that and it would not affect the argument. The magnitudes of thermal and strain energy are probably of the same order; however, this point is difficult to guess or calculate. The mechanism described would predict a fairly well-defined brittle temperature in the transition region of a material for which the transition itself is sharp also, as is found in plasticized poly(vinyl chloride) compositions.

A more complex situation arises in the case of partially crystalline polymers, in which a number of factors tend to broaden the distribution of fractures. First, crystallinity flattens the slope of the modulus curve, and hence of the energy density curve, in the transition region; it is obvious from Fig. 6 that this will widen the range $T_{f'}$ to $T_{f''}$. Second, three regions may be distinguished in a crystallizing polymer, the crystalline and amorphous phases and the boundary between them; thus both the total energy density E_v during straining and the critical energy E_f will in general be variable from point to point in a material. This is equivalent to saying that fracture depends in part on what was previously called fixed faults (for example, a locally unfavorable configuration lowering E_f or raising E_v) but also, that the lines of E_f and E_v in Fig. 6 are replaced by bands, resulting in a broadened distribution of fractures. Further, one may expect an effect of annealing, which changes the organization of crystallites and spherulites; further detailed assumptions would be required to explain the rise of brittle temperature with increasing efficiency of annealing.

The suggested explanations just given qualitatively fit the behavior of polytetrafluoroethylene which has a mechanical transition around −80 C and polyethylene which has one around −110 C. That in polyethylene the brittle temperature can lie much above −110 C appears to be mainly associated with its peculiar notch sensitivity, but also with the fact that a second transition around 0 C exists; the dynamic modulus continuously decreases with rising temperature in between transitions. The notch effect is usually regarded as a consequence of increased strain energy density at the notch bottom; the effect of our argument on the

E_v curves will be to move them upwards along the ordinate and to steepen their slope, as represented on the idealized graph in Fig. 7; this figure also illustrates the expected consequence; T_{50} moves to higher temperatures and σ diminishes, as was in fact found to be the case. There is also a molecular weight effect in polyethylene, that is, T_{50} drops and σ increases with decreasing melt flow index; there appears to be no difficulty to fit this effect in, with some elaboration of the assumptions, but again the point will not be pursued to avoid encumbering the main line of argument.

Acknowledgment:

The authors wish to acknowledge the assistance given by B. J. Stay with the experimental and computational work.

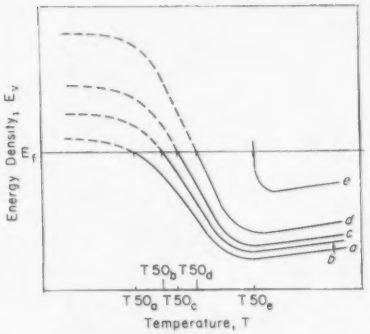


Fig. 7.—Maximum energy density curves for polyethylene specimens differently prepared.

a is the least damaged specimen. *e* is a specimen deliberately notched. Increasing damage to specimen during preparation raises T_{50} and narrows the distribution. A notched specimen is the limiting case. Fo rall energies greater than E_f the energy density curves cannot represent a real situation.

Summary

It is shown that conventional low-temperature brittleness tests (for example ASTM Method D 746 – 55 T)[3] do not give unique "low-temperature brittleness" values for polyethylene. The test results depend to a marked extent on the state of the specimen, that is on the method of specimen preparation. If brittle test results on polyethylene are to be meaningful, and comparable between laboratories, a more stringent test specification is necessary to cover specimen preparation and conditioning (annealing). Alternatively, a test on notched specimens may be substituted; it may be better for assessing serviceability, since it gives a much closer estimate of the temperature limit for no failures. Further advantages are that it preserves the distinction between samples of polyethylene of different melt flow index and that it avoids the necessity to prepare, meticulously, large numbers of specimens.

A proposed mechanism of failure explains qualitatively the effects of various factors affecting the test result.

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(1) E. F. Smith and G. J. Dienes, ASTM Bulletin, No. 154, Oct., 1948, p. 76.
(2) D. J. Finney, *Probit Analysis*, Cambridge Univ. Press, Cambridge, England (1952).

U.S. Host to ISO Plastics in 1958

TECHNICAL COMMITTEE 61 on Plastics of the International Organization for Standardization (ISO) at its meeting July 8–13, 1957, in Burgenstock, Switzerland, agreed to hold its Eighth Annual Meeting in the United States at the invitation of the American Group. The American Group has set the date in October of 1958 and plans are going forward for an international symposium on plastics to be held in Philadelphia the week preceding the ISO 61 meetings in Washington.

Notable progress in international standardization in plastics test methods was reported at the Burgenstock meeting. Ninety-five delegates from fifteen participating countries attended. Observers were present from the International Electrotechnical Commission (IEC), the International Union of Pure and Applied Chemistry (IUPAC), and the International Congress on Plastic Materials (ICPM). Twelve test methods for plastics approved for circulation to member countries included six draft ISO proposals and six recommendations. Four were approved for final action by the ISO Council.

The United States was represented by C. Howard Adams, leader of the U. S. delegation, Monsanto Chemical Co.; Robert Burns, Materials Advisory Board, National Academy of Sciences; G. M. Kline, National Bureau of Standards; N. A. Skow, representing Society of Plastics Engineers, Synthane Corp.; A. C. Webber, E. I. du Pont de Nemours and Co.; P. E. Willard, Ohio-Apex Div., Food Machinery and Chemical Corp.; R. K. Witt, Johns Hopkins University; K. Y. Wolford, Koppers Co., Inc.

Dr. G. M. Kline presided as chairman of the meeting, Dr. W. Frisch (Ciba Co., Switzerland) was co-chairman, and N. A. Skow and N. Maurer (Switzerland) served as technical secretaries.

The American Group for ISO 61 on Plastics functions as a subcommittee of ASTM Committee D-20 on Plastics.

Fifteen Years of Porcelain Enamel Weathering

SINCE 1939 the National Bureau of Standards has maintained a large number of porcelain enamel samples for study of weather resistance. Fourteen types of enamels utilizing 864 panels were exposed to four different climatic conditions at Atlantic City, N. J., Lakeland, Fla., St. Louis, Mo., and Washington, D. C.

After 15 years' exposure it was found that no corrosion occurred regardless of the type of enamel applied so long as the enamel completely covered the metal. At points of poor coverage, the enamel spalled away from the opposite side of the panel, even though corrosion had penetrated only part of the way through the base metal.

Evaluation of the relative weathering resistance of the enamels was made by measuring changes in specular gloss and in color.

The test measurements on the panels showed that the more acid-resistant enamels were also more resistant to weathering. The highly acid-resistant enamels were also easier to clean after 15 years' exposure.

The more acid-resistant enamels also maintained their color, with the exception of a few red enamels. Apparently the cadmium-selenium-sulfur reds slowly oxidized and thus paled over the years.

Among the recommendations made by the Bureau from this test, the one that may prove to be of greatest usefulness for specification purposes is that for architectural installations where general appearance, absence of fading, and ease of cleaning are important, only enamels having class A or class AA acid resistance by the ASTM Standard Methods of Test for Acid Resistance of Porcelain Enamels (C 282 – 53) may be acceptable.

The Bookshelf

Basic Chemistry of Textile Preparation

S. R. Cockett and K. A. Hilton; Philosophical Library, Inc., New York, N.Y.; 197 pp.; $6

ACCORDING to the publisher, this little book with its companion volume "Basic Chemistry of Textile Colouring and Finishing" is intended to provide a complete theoretical course in basic textile chemistry for students and for workers already in the industry.

Chapters 1 to 4 deal, respectively, with fiber structure, optical and electron microscopy, and X-ray diffraction; the chemistry of the natural fibers; polymerization and the structure and properties of plastics and related materials; and the manufacture and chemistry of man-made fibers. Chapter 5 consists of tables giving the properties of the better known natural and man-made fibers. This is followed by a chapter on preparatory processes which accounts for about 15 per cent of the text and which covers hardness in water, wetting and detergency, methods for cleansing various fibers, mercerizing, creping, and chlorination, milling, and carbonizing of wool. The three remaining chapters deal with chemical and optical bleaches; the physics and chemistry of color; the paper, leather, laundering, and dry cleaning industries; fiber identification; physical testing; and the detection of fiber damage.

The level of the subject matter suggests that the book will be of little value to advanced students or chemists working with textiles. It may be helpful to beginning students and to chemists from other fields who wish to acquire a general knowledge of the textile industry. As knowledge of organic chemistry is presupposed, the book is not suitable for the layman. A number of errors detract from the text.

F. H. FORZIATI

The Specification and Management of Materials in Industry

T. H. Starr; Thomas and Hudson Ltd., London; 184 pp. 21/.

The theme stressed by the author is the formation and use of standards departments for individual companies. Illustrating his discussion with examples from British industry, the author points out cost savings and operation efficiencies derived from central standards departments. Included in the book are descriptions of technical purchasing, use of purchasing specifications, organization methods for standards departments, and methods for materials inspection.

The author gives in some detail methods for management utilization and control of standards work including the regulation of relations with other departments, the conduct of materials engineering offices and laboratories, and the selection and use of personnel. Several chapters are devoted to numbering systems, the writing of purchasing specifications, the writing of process specifications, and the selection and use of approved suppliers. The book covers not only materials standards but also specifications for components and processes.

Considerable discussion of government and national standards such as those of BSI and ASTM is given. The author also refers to the use of individual company standards tailored to specific needs rather than using more widely accepted national standards. While he mentions the hazards associated with "specials," he in general overrides these objections. Proper management, he feels, can intelligently control company specifications. National standards, he states, should be used only as general guidance.

The book is thorough and comprehensive. It takes an elementary approach to a complex subject and although there are flaws in the arguments presented it contains information for those not well versed in standardization work.

A.L.B.

Windows and Glass in the Exterior of Buildings

Publication 478. Building Research Institute, Div. of Engineering and Industrial Research, National Academy of Sciences, National Research Council, 2101 Constitution Ave., Washington, D. C.; $5.

AN INTERESTING group of papers presented at a research correlation conference conducted by the Building Research Institute in 1956, is found in a published report now available. The conference had as its primary objective discussion of the new and untraditional ways in which glass, windows, and related products are being used today in buildings of all types.

Within the pages of this publication, a number of research directors detail some of their most recent findings in the field of daylighting; heating, air conditioning and ventilating engineers discuss problems and solutions; manufacturers describe new types of windows, new uses for glass; building owners relate their experiences with controls, and the reactions of occupants; control experts point out the benefits and detriments of interior and exterior control systems; architects discuss residential, commercial, and institutional construction.

No attempt is made to determine whether or not there should be glass in a building, or how elaborate the design applications should be. The Building Research Institute has acted as a forum in which a balance of industry, professional, and academic opinion was presented in the interest of the advancement of new research and development.

Underground Corrosion

National Bureau of Standards Circular 579; Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 227 pp. $3.

THIS CIRCULAR, which supersedes NBS Circular 450 issued in 1945, is a final report on the studies of underground corrosion conducted by the Bureau over a period of 45 years. Up to 1922, the studies were confined to corrosion due to stray-current electrolysis and its mitigation. After it became apparent that serious corrosion occurred in soils under conditions that precluded stray-currents as an explanation, a field burial program was initiated in order to obtain information pertaining to the effect of soil properties on the corrosion of metals. Approximately 37,000 specimens, representing 333 varieties of ferrous, nonferrous, and protective coating materials, were exposed in 128 test locations throughout the United States. During this time the electrical and electrochemical aspects of underground corrosion, including cathodic protection, have been continuously studied in the laboratory. Results from both field and laboratory investigations are presented in the circular. Also included are many references to industrial investigations and field experiences related to the Bureau's underground corrosion investigations.

Design Properties of High Strength Steels in the Presence of Stress Concentrations and Hydrogen Embrittlement

Technical Report 56-395, Air Research and Development Command, U.S.A.F. Wright-Patterson A.F.B., Ohio.

THE EMBRITTLEMENT of high-strength steels due to the action of hydrogen introduced by cadmium electroplating has been studied in sustained-load, rotating-beam fatigue, and bending tests. Strength levels from 180,000 to 300,000 psi as suitable for the various steels were examined for a variety of initial conditions of stress concentration.

All steels were found to be embrittled in some measure after cadmium plating, and this embrittlement could not be fully eliminated, as determined in the bend test, through the baking treatment used. The improvement in properties

(Continued on page 92)

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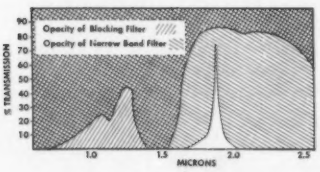

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#1 FATIGUE

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FATIGUE STATISTICAL ASPECTS OF—STP 121 Planning and Interpretation of Fatigue Tests; Statistical Nature of Fatigue; Statistical Analysis of Fatigue Data; plus prepared discussions. 72 pages. (March, 1952.)	$ 1.75	$1.35		
FATIGUE, WITH EMPHASIS ON STATISTICAL APPROACH—II—STP 137 Papers point out the definite need for a statistical approach to the interpretation of fatigue data. Statistical Nature of the Fatigue Properties of SAE 4340 Steel Forgings; Statistical Behavior of Fatigue Properties and the Influence of Metallurgical Factors; Statistical Interpretation of the Effect of Understressing; and Fatigue Properties of Large Specimens with Related Size and Statistical Effects. 96 pages. (February, 1953.)	2.00	1.50		
FATIGUE TESTING, MANUAL ON—STP 91 Prepared by Committee E-9 on Fatigue is to supply information to those setting up new laboratory facilities, to aid in operating the equipment properly, and to offer advice in presentation and interpretation of the data. The manual concerns itself with fatigue testing and not with fatigue of metals as such. 86 pages. (December, 1949.)	2.50	1.85		
Total	$ 6.25	$4.70	$4.75	$3.50

#2 METALS

CORROSION- AND HEAT-RESISTANT STEELS AND ALLOYS—WROUGHT AND CAST, DATA ON—STP 52-A This publication, sponsored by Committee A-10 on Iron-Chromium-Nickel and Related Alloys, presents data on the compositions and properties of the wrought corrosion-resistant and heat-resistant chromium and chromium-nickel steels and alloy castings. 84 pages. (May, 1950.)	$ 2.50	$1.85		
COLOR, METALLOGRAPHY IN—STP 86 The book is illustrated with four-color process photomicrographs. Subjects covered include the following: Microscope Optics for Color Metallography; Quality and Quantity of Illumination in Metallography; Color Metallography Simplified; Some Applications of Color Metallography; Application of Color Photography to the Study of Nonmetallic Inclusions. 72 pages, plus 10 colored insert plates. (December, 1949.)	5.15	4.05		
STAINLESS STEELS, EVALUATION TESTS FOR—STP 93 The symposium covers corrosion resistance, mechanical properties, and intergranular susceptibility of 18-8 stainless steels with and without additions of columbium or molybdenum or both. Data are given on comparative corrosion resistance of stainless steels in various acids as well as the results of some plant corrosion tests. 240 pages. (May, 1950.)	2.50	1.85		
SIGMA PHASE, NATURE, OCCURRENCE, AND EFFECTS OF—STP 110 Nine papers discuss sigma phase, particularly as related to austenitic steels, and various chrome, nickel alloys. 204 pages. (January, 1951.)	2.50	1.85		
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#3 SOAPS

DETERGENT LABORATORY, STATISTICAL METHODS FOR THE THE—STP 139 These papers describe the use of correlation, analysis of variance, tests for significance, and some ingenious graphical methods of statistical analysis. 44 pages. (January, 1953.)	$ 1.50	$1.15		
SOAPS AND DETERGENTS, PAPERS ON EVALUATION OF—STP 115 The papers include: An *In-vivo* Method for Determining the Degerming Efficiency of Soaps Containing Hexachlorophene; The Mechanism of the Wetting of Textiles; Practical Evaluation of Soiled Test Pieces; Laboratory Performance Test for Detergents in Continuous Wool Scouring; and Measurement of the Adsorption of Anion-Active Detergents by Materials Commonly Washed. 64 pages. (January, 1952.)	1.25	1.00		
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GREASES, FUNCTIONAL TESTS FOR BALL-BEARING—STP 84 Papers cover: development of functional grease methods for aircraft industry; grease—an oil storehouse for bearings; laboratory performance tests for antifriction bearing greases; factors affecting simulated service tests of greases. 104 pages. (November, 1948.)	1.00	.75		
PETROLEUM CHEMISTRY, AN EXCURSION IN (Marburg Lecture, 1953), by F. D. Rossini, Director of the Petroleum Research Laboratory, Carnegie Institute of Technology. 32 pages. (Reprint from *Proceedings*.)	1.00	.75		
LUBRICANTS, INDUSTRIAL GEAR—STP 88 This symposium includes papers covering: Heavy Duty Gear Oils; Gear Lubricants Used in Steel Plants; Gear Set Servicing by the Cathode Ray Oscilloscope. 24 pages. (April, 1949.)	.75	.60		
LUBRICATION OF HIGH-SPEED TURBINE GEAR EQUIPMENT—STP 92 Lubrication of Naval Gearing; Developments in Gear Design and Lubrication Requirements; Concepts of Lubricating Oil Wedge and its Load-Carrying Capacity for Mating Tooth Surfaces of High-Speed Gears; and Fundamentals of Worm Gear Lubrication. 32 pages. (August, 1949.)	.75	.60		
Total	$ 4.00	$3.10	$3.00	$2.25

#5 SOILS

SOILS, CONSOLIDATION TESTING OF—STP 126 Among the papers included are Report of Consolidation Tests with Peat; Consolidation and Related Properties of Loess Soils; Settlement of the Railroad Embankment Crossing of the Morganza Floodway, Louisiana. 100 pages. (September, 1952.)	$ 1.75	$1.35		
PERMEABILITY OF SOILS—STP 163 Some papers covered principles of permeability testing of soils; water movement through porous hydrophilic systems under capillary, electric, and thermal potentials; permeability test for sands; low-head permeameter for granular materials. 142 pages. (March, 1955.)	3.00	2.25		
SOILS AND BITUMINOUS MIXTURES, TRIAXIAL TESTING OF—STP 106 History and theory of triaxial testing and the preparation of realistic test specimens; applications to bituminous mixtures; application to the design of bituminous pavements; triaxial testing, adapted to soils.	3.50	2.60		
SOILS, IDENTIFICATION AND CLASSIFICATION OF—STP 113 This symposium describes and evaluates the most widely used procedures for identifying and classifying soils for engineering purposes. 96 pages. (April, 1951.)	1.65	1.25		
SURFACE AND SUBSURFACE RECONNAISSANCE—STP 122 Papers are divided into four general groups; pedologic, geologic, air photo, and geophysical, in accordance with the procedures used for making the reconnaissance. 226 pages. (August, 1952.)	3.00	2.25		
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PERSONALS...

News items concerning the activities of our members will be welcomed for inclusion in this column

Recently appointed 1957–58 chairmen of committees of the American Electroplaters' Society include the following, also active in ASTM Committee B-8 on Electrodeposited Metallic Coatings: **Robert A. Ehrhardt,** of Bell Telephone Labs., Inc., who heads the Research Committee; **Ralph Schaefer,** of Clevite-Brush Development Co., Div. of Clevite Corp., serving as chairman of the Publications Committee; and **Ralph D. Wysong,** of Studebaker-Packard Corp., heading the Membership Committee.

Ludwig Adams, formerly with Pittsburgh-Des Moines Steel Co., is now staff associate, Development and Research, Blaw-Knox Co., Pittsburgh, Pa.

Roger Gordon Bates has been appointed chief of the Physical Chemistry Section of the National Bureau of Standards, Washington, D. C. An internationally known authority on pH measurement, Dr. Bates has been a member of the Bureau staff since 1939. In ASTM he has been active in the subcommittee concerned with hydrogen ion determinations of Committee E-1 on Methods of Testing and headed the committee that sponsored the 1956 Symposium on pH Measurement.

Elmer O. Bergman, technical adviser, C. F. Braun and Co., Alhambra, Calif., was renominated to serve for a four-year term as Director (Codes and Standards) of The American Society of Mechanical Engineers. In ASTM Dr. Bergman is a member of Committee A-1 on Steel and has been very active for many years in Southern California District work. He is a past-chairman of the District Council, and served as Vice-Chairman of the General Committee on Arrangements for the Second Pacific Area National Meeting in Los Angeles in September, 1956.

Philip T. Bodell, formerly textile research engineer with Collins & Aikman Corp., is now president, Bristol Research Associates, Inc., Bristol, R. I.

Leonard S. Buchoff, until recently on the engineering staff, Westinghouse Electric Corp., Pittsburgh, Pa., is now chemical engineer, Electro Tec Corp., Ormond Beach, Fla.

Kenneth P. Campbell has been appointed general superintendent, operations, Houston plant, Sheffield Div., Armco Steel Corp. He had been superintendent of metallurgy. Mr. Campbell is an active member of the ASTM Southwest District Council, serving as District Membership Chairman.

L. J. Demer is now associated with Rias, Inc., Baltimore, Md., as staff scientist. He was formerly research fellow, University of Minnesota, Engineering Experiment Station, Minneapolis.

Edgar W. Engle, until recently technical director for Vascoloy-Ramet Corp., Waukegan, Ill., has been appointed as development engineer by Kennametal, Inc., Latrobe, Pa. Mr. Engle will be concerned with development of new products in connection with the company's current expansion program. In ASTM he has been very active in Committee B-9 on Metal Powders and Metal Powder Products, serving as chairman of Section C on Cemented Carbides of Subcommittee III.

Francis B. Foley has been named executive metallurgical engineer of Pencoyd Steel and Forge Corp., Philadelphia, Pa. For many years with the Midvale Co., and more recently consulting metallurgist to International Nickel Co., New York City, with which organization he is still affiliated, Mr. Foley has been very active in ASTM metals committees over a long period.

James L. Foster has been promoted to a more responsible position as group leader in silicate research for Diamond Alkali Co.'s Silicate, Detergent, Calcium Division, Cleveland, Ohio. His new responsibilities will include maintenance and improvement of quality control standards at Diamond silicate plants at six locations.

A. K. Frolich has retired as vice-president and chief engineer, Ash Grove Lime and Portland Cement Co., Kansas City, Mo.

Almon H. Fuller, on the faculty of the Civil Engineering Department, Iowa State College, for 37 years, retired recently after teaching engineering for 60 years. Before going to Iowa State as head of the Civil Engineering Department in 1920, he was professor of civil engineering and dean of the College of Engineering at the University of Washington (1898–1917), and subsequently for three years he served as head and professor of civil engineering at Lafayette College, Easton, Pa. He was awarded an honorary doctor of science degree by Lafayette in 1936, an honorary doctor of engineering degree by Iowa State in 1955, and was honored as professor emeritus by the Iowa Board of Regents, July 1, 1957. Dr. Fuller has served also as a consultant and structural

(*Continued on page 74*)

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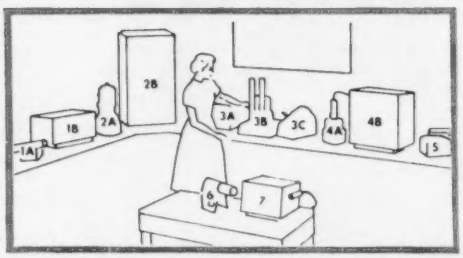

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FOR FURTHER INFORMATION CIRCLE 667 ON READER SERVICE CARD PAGE 105

Personals

(*Continued from page 72*)

designer of buildings and bridges, and was author or co-author of several books on designing and testing steel structures. His most recent work, "A History of Civil Engineering at Iowa State College" is to be published soon. A member of ASTM since 1903, Dr. Fuller now resides at Wesley Gardens, Des Moines, Wash.

L. F. Goss has retired as chief engineer, Kuhlman Electric Co., Bay City, Mich.

D. F. Gould is retiring as assistant to the technical director, Chemical Div., The Borden Co., New York City. Mr. Gould has been representing The Borden Co. in the Society and on several of the technical committees for a number of years. Previously associated with Allied Chemical and Dye Corp., Barrett Div., and representative also of that company in ASTM, Mr. Gould's technical committee service has spanned the past three decades. His most intensive activity has been in Committee D-16 on Industrial Aromatic Hydrocarbons and Related Materials, of which he is a charter member. He has been serving as chairman of this main group since 1946.

S. H. Greenfield, formerly research chemist, Asphalt Roofing Industry Bureau, National Bureau of Standards, Washington, D. C., is now research engineer, California Research Corp., Richmond, Calif.

John M. Holt has been appointed an assistant technologist in the Sheet Products Div., United States Steel Corp., Applied Research Lab., Monroeville, Pa.

Clyde W. Kelly, chief engineer, Window and Door Div., Fenestra, Inc., Detroit, Mich., since 1952, has been appointed director of engineering research for that company. Affiliated with ASTM since 1937, Mr. Kelly has been serving on Committee E-5 on Fire Tests of Materials and Construction and its subcommittee concerned with fire tests of wall opening assemblies.

Bertrand A. Landry has been named an assistant technical director at Battelle Memorial Inst., Columbus, Ohio. A veteran member of the Battelle staff, Mr. Landry, one of the country's leading technologists in the field of combustion and energy, has just returned from Paris, France, where for the past three years he has been in charge of the Institute's office in that city. Active in a number of technical organizations, he has served for many years on ASTM Committee D-5 on Coal and Coke, and its subcommittee concerned with sampling.

Robert W. Lindsay has joined Crucible Steel Co. of America as supervisor of constructional alloy steels at its research laboratory in Pittsburgh, Pa. He was professor of metallurgy at Pennsylvania State University.

ASTM Director **Ernest F. Lundeen,** retired superintendent, Service Dept., Inland Steel Co., Chicago, Ill., is now consultant, Rheem Mfg. Co., Automotive Div., Fullerton, Calif.

Claude B. McIntosh, formerly development engineer, Jet Div., Thompson Products, Inc., Cleveland, Ohio, is now senior analysis engineer, Marquardt Aircraft Co., Santa Monica, Calif.

D. J. McKinnon, formerly assistant chief engineer for Fenestra, Inc., Detroit, Mich., has been appointed chief product engineer of the company's building products division. A member of ASTM since 1943, Mr. McKinnon has been serving on Committee A-5 on Corrosion of Iron and Steel and its subcommittees concerned with hardware specifications and tests; and presently is Secretary of the Detroit District Council.

William H. Morris retired as general consultant, Research Div., Keasbey & Mattison Co., Ambler, Pa., after 48 years of continuous service, during which he held positions as assistant to chief chemist, chief chemist, assistant superintendent, assistant general superintendent, and director of the chemical laboratory in the power products plant, working on research development and quality control, becoming general consultant of the research division in 1940. Mr. Morris had represented his company on ASTM Committee D-13 on Textile Materials since 1926.

Lawrence L. Neebe has retired as chief engineer, Magnus Metal Div., National Lead Co., New York City. Mr. Neebe had been representing his company in the Society and on Committee B-2 on Non-Ferrous Metals and Alloys. He is succeeded as chief engineer by **M. A. Hanson** who now will serve as representative of the Magnus Metal Div.

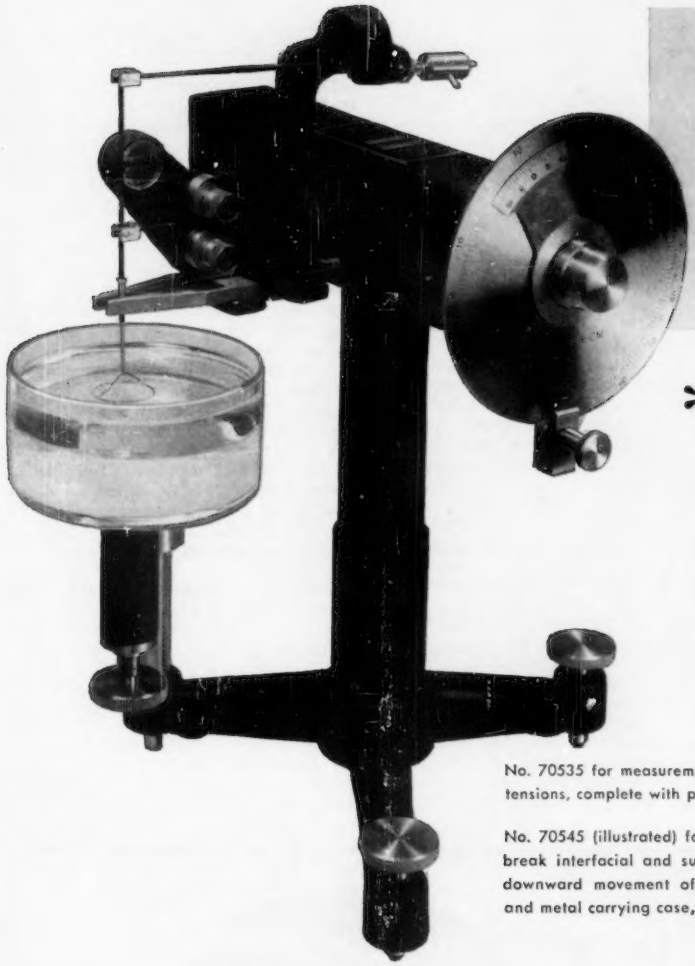
Clifford A. Neros has been promoted to group leader in the Product Development Section, Central Research Dept., Diamond Alkali Co., Cleveland, Ohio. Dr. Neros, who represents his company in the Society and on Committees D-9 on Electrical Insulating Materials, and D-20 on Plastics, will continue to direct laboratory work relating to product evaluation and applications research on new chemicals and plastics at the Diamond Research Center.

Charles W. Ostrander has been made technical director, Allied Research Products, Inc., Baltimore, Md.

J. E. Palmer has retired as supplies inspection superintendent, Western Electric Co., New York City. He is succeeded by W. F. Gannon.

William James Putnam is now professor (emeritus) of theoretical and applied mechanics, University of Illinois. Professor Putnam, who has been an ASTM member since 1918, resides at 610 W. Illinois St., Urbana, Ill.

(*Continued on page 76*)



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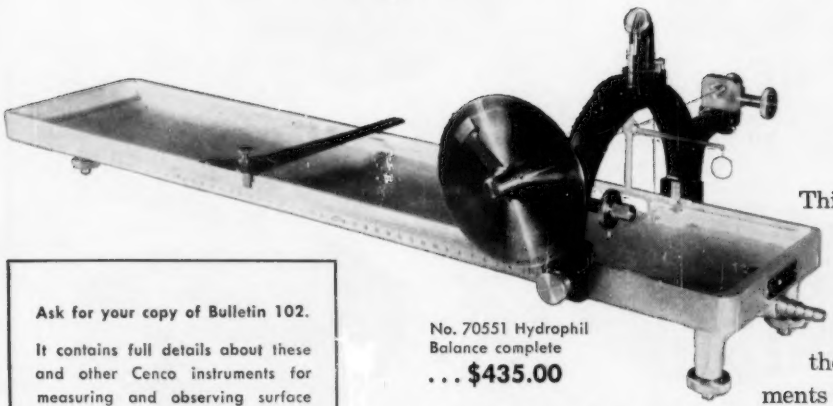

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FOR FURTHER INFORMATION CIRCLE 669 ON READER SERVICE CARD PAGE 105

Personals

(*Continued from page 74*)

Kurt F. Richards, formerly technologist, Amoco Chemicals Corp., Chicago, Ill., is now technical editor, Esso Research and Engineering Co., Linden, N. J.

D. F. Sawtelle, until recently chief metallurgist, Malleable Iron Fittings Co., Branford, Conn., has joined Exomet, Inc., Conneaut, Ohio, with headquarters in Chicago.

Charles E. Schaffner, formerly assistant dean, has been appointed associate dean of the Polytechnic Institute of Brooklyn. Prior to the appointment Dean Schaffner was professor of civil engineering and director of the evening session. Dean Schaffner has served as chairman of the Evening Engineering Education Division of the American Society for Engineering Education.

George V. Smith has been named director of metallurgical engineering at the school of chemical and metallurgical engineering at Cornell University, Ithaca, N. Y. Dr. Smith joined the Cornell faculty in 1955 as Francis Norwood Bard professor of metallurgical engineering, after 14 years with the U. S. Steel Corp., Kearny, N. J., research laboratory. While associated with U. S. Steel, he taught graduate night courses in metallurgy at Polytechnic Institute of Brooklyn. Dr. Smith has been active for many years in the Joint ASTM-ASME Committee on Effect of Temperature on the Properties of Metals.

William C. Stewart, since 1937 affiliated with the Industrial Fasteners Institute, and for many years technical adviser and treasurer, was honored at a dinner party given by his friends and associates in New York City on Wednesday, September 11, commemorating his twentieth anniversary in this important work. Quite a number of ASTM members were present, many active in technical committee work where Mr. Stewart has labored hard to develop needed specifications and tests. For many years he was secretary of the Section on Bolting in Committee A-1's Subcommittee XXII, and helped organize and was active in Subcommittee XXVI on Bolting. He aided also in other capacities. Representatives of a number of societies spoke briefly at the reception prior to the dinner, including representatives from AREA, SAE, ASME; and Executive Secretary Robert J. Painter commented on Stewart's ASTM work.

Joseph W. Tomecko, assistant general manager, Paints Div., Canadian Industries, Ltd., Montreal, Canada, will assume the presidency of the Federation of Paint and Varnish Production Clubs at the 35th annual meeting in Philadelphia, Pa., October 30–November 2. **Albert C. Zettlemoyer,** professor of chemistry, Lehigh University, and director of research, National Printing Ink Research Institute, is scheduled to deliver the 1957 Mattiello Lecture on "The Pigment-Vehicle Interface."

Carrol M. Wakeman, materials testing engineer, Los Angeles Harbor Dept., Wilmington, Calif., was recipient of the 1957 William F. Clapp Memorial Award presented by the Sea Horse Inst. for "outstanding contributions to marine biology." The Institute, an international association of engineers engaged in testing of materials in sea water, makes the award annually to the member most distinguishing himself in the field. Mr. Wakeman, who has been with the Harbor Department since 1922, represents the Department membership in ASTM, also on Committees C-9 on Concrete and Concrete Aggregates, and D-19 on Industrial Water. He has been very active in the Southern California District activities of the Society, and is a past-chairman of the District Council. He further rendered valued aid as chairman of the General Committee on Arrangements for the Second Pacific Area National Meeting in Los Angeles in September, 1956.

Henry A. Weigand, formerly with Concrete Conduit Co., Azusa, Calif., is now on the engineering staff of Southern Cen-Vi-Ro Pipe Corp., Jacksonville, Fla.

Clyde E. Work, formerly associate professor of mechanics, Rensselaer Polytechnic Institute, Troy, N. Y., is now professor and head, Department of Engineering Mechanics, Michigan College of Mining and Technology, Houghton, Mich.

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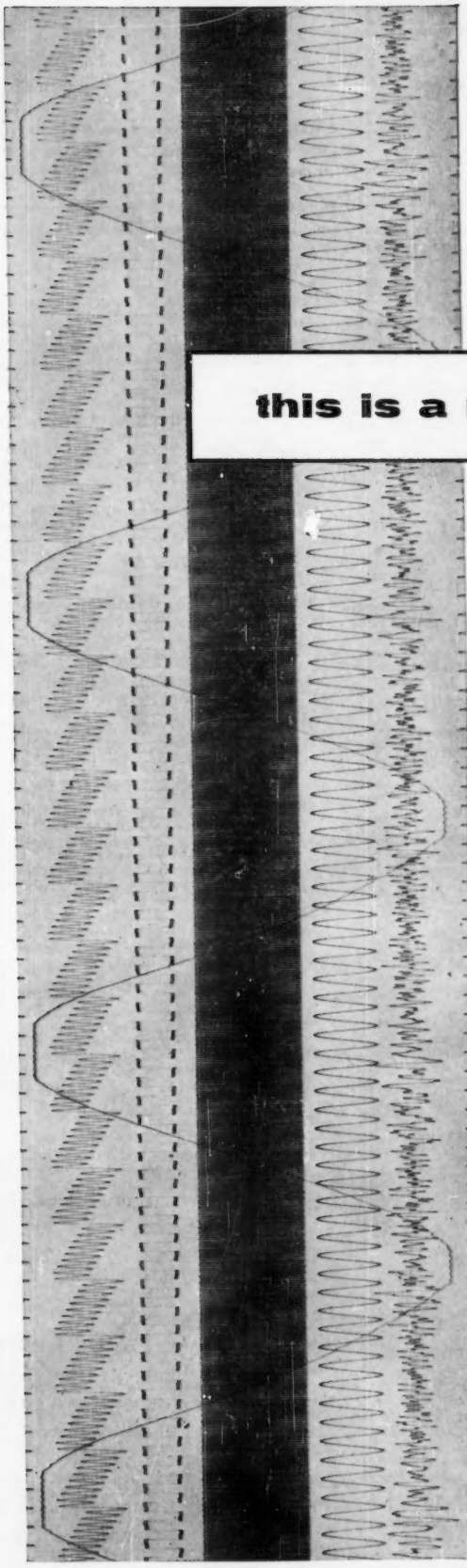

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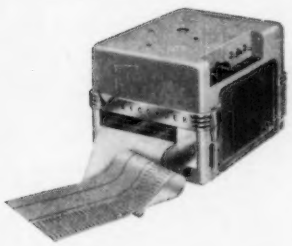

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FOR FURTHER INFORMATION CIRCLE 675 ON READER SERVICE CARD PAGE 105

NEW MEMBERS.....

The following 74 members were elected from August 15 to September 17, 1957 making the total membership 9066... Welcome to ASTM

Note—Names are arranged alphabetically—Company members first then individuals.—Your ASTM Year Book shows the areas covered by the respective Districts

CHICAGO DISTRICT (5)

International Minerals and Chemical Corp., Marion L. Tomkins, spectrographer, Central Research Lab., 5401 Harrison St., Skokie, Ill.

Morrison Construction Co., Inc., R. J. Betters, general manager, 1834 Summer St., Hammond, Ind.

Brown, Shirley K., vice-president and secretary, Aluminum Refining Corp., Box 447, Sheboygan Falls, Wis. For mail: 2733 Highland Terrace, Sheboygan, Wis.

Viest, Ivan M., bridge research engineer, National Academy of Sciences, AASHO Road Test, Box 539, Ottawa, Ill.

CLEVELAND DISTRICT (4)

Cunningham, John W., consulting engineer, 134 E. Thornton St., Akron 11, Ohio.

Hurd, A. Bentley, Qualitative Control, Duracote Corp., 350 N. Diamond St., Ravenna, Ohio.

Spragg, J. Dennis, assistant chemist, South Div., Republic Steel Corp., 2149 Harrison Ave., S. W., Canton, Ohio. [A]*

DETROIT DISTRICT (6)

Goff, James W., assistant professor, Michigan State University, School of Packaging, B-4 S. Campus, East Lansing, Mich.

NEW ENGLAND DISTRICT (13)

Aldrich, Harl P., Jr., partner, Haley & Aldrich, 238 Main St., Cambridge 42, Mass.

Anderson, Walter A., head of physical testing lab., Simplex Wire and Cable Co., 79 Sidney St., Cambridge 39, Mass.

Davis, Ralph P., works engineer, Walworth Co., First and O Sts., South Boston 27, Mass.

U. S. Naval Construction Battalion Center, Edmund C. Pickard, director, Standardization Div., Technical Dept. 7, Davisville, R. I.

NEW YORK DISTRICT (1)

Gasoline Pump Manufacturers Assn., Richard L. Demmerle, technical director, 420 Lexington Ave. New York 17, N. Y.

Raybestos-Manhattan, Inc., Edward V. Huda, project supervisor, Box 1021, Bridgeport 2, Conn.

Bergen, J. H., Engineering Services Lab., American Machine and Foundry Co., Box 889, Stamford, Conn.

Brennan, John F., resident partner, Dames & Moore, 140 Cedar St., New York 6, N. Y.

Coykendall, William E., Jr., sales manager, Alite Div., U. S. Stoneware Co., 60 E. 42nd St., New York 17, N. Y.

Gannon, W. F., superintendent, supplies inspection, Western Electric Co., Inc., 401 Hudson St., New York 14, N. Y.

Jaglom, Jacob, plant manager, Corroplast, Inc., 100 Dayton Ave., Passaic, N. J.

Kemelhor, R. E., chief engineer, McLean Development Labs., Inc., Strong Ave., Copiague, L. I., N. Y. For mail: 27 Secatogue Lane, West Islip, N. Y.

Mullen, Wesley Grigg, resident engineer, Madigan-Hyland, Consulting Engineers, 28-04 41st Ave., Long Island City, N. Y. For mail: RFD 1, Kinderhook, N. Y.

Royle, Robert J., sales manager, International Wire Products Corp., Greenwood Ave., Midland Park, N. J. For mail: 23 Park Dr., Ossining, N. Y.

Siagle, George H., Methods and Research, Volco Brass and Copper Co., Kenilworth, N. J.

Smith, Luther H., engineer, Aircraft Products Dept., General Electric Co., Bldg. 28, Room 126C, Schenectady 5, N. Y.

Steger, Aaron, naval stores chemist, U. S. Department of Agriculture, New York, N. Y. For mail: 115 Winding St., Huntington, L. I., N. Y.

Swackhamer, F. S., director, Technical Service Lab., Shell Chemical Corp., 1120 Commerce Ave., Union, N. J.

Tirpak, John J., design engineer, Kearfott Co., Inc., 1378 Main Ave., Clifton, N. J. For mail: 77 Ravine Ave., West Caldwell, N. J.

Wang, Sidney, laboratory director, Consolidated Testing Lab., 79 Herricks Rd., New Hyde Park, L. I., N. Y.

NORTHERN CALIFORNIA DISTRICT (8)

California, State of, Division of Architecture, Mechanical Section, Mechanical Supervisor, Box 1079, Sacramento, Calif.

OHIO VALLEY DISTRICT (15)

Aeronca Manufacturing Corp., Herbert J. Davis, supervisor, Engineering Lab., Germantown Rd., Middletown, Ohio.

MacIntosh, Robert M., manager, Tin Research Inst., Inc., 492 W. Sixth Ave., Columbus 1, Ohio.

PHILADELPHIA DISTRICT (2)

Curry, John J., vice-president, Plumb Chemical Corp., 4837 James St., Philadelphia 37, Pa.

New Jersey State Highway Dept., L. C. Petersen, director and chief bridge engineer, 1035 Parkway Ave., Trenton 25, N. J.

Shotwell, Raymond H., senior engineer, A. C. Jones Associates, 223 High St., Mt. Holly, N. J. For mail: 1 S. Main St., Lumberton, N. J.

PITTSBURGH DISTRICT (3)

Bailey, Preston F., manager, application engineering, Mine Safety Appliances Co., 201 N. Braddock Ave., Pittsburgh 8, Pa.

Patsey, John A., research engineer, Aluminum Company of America, Alcoa Research Labs., Box 772, New Kensington, Pa. [A]

ST. LOUIS DISTRICT (9)

St. Louis Solvents and Chemical Co., James McQuie, technical director, 7882 Folk Ave., St. Louis 17, Mo.

Schindler, Albert R., plant engineer, Owens-Corning Fiberglas Corp., Box 326, Kansas City, Kans. For mail: 4235 N. Elmwood, Kansas City 16, Mo.

Young, Robert L., Jr., chemist, Cherokee Lab., International Shoe Co., 1820 Cherokee, St. Louis 18, Mo.

SOUTHEAST DISTRICT (17)

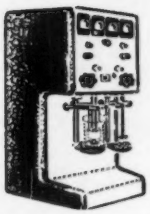
Ballenger Paving Co., Inc., C. P. Ballenger, Jr., president, Box 927, Greenville, S. C.

Dykes, Carrel H., chief engineer, Neco Electrical Products Corp., Bay Springs, Miss. For mail: Box 215, Bay Springs, Miss.

Fellman, Morton R., chief engineer, Constructors Laboratories, Inc., 1414 S. W. Flagler Terrace, Miami 35, Fla.

Payne, Charles, chief engineer, Charles Payne and Associates, Consulting Engineers, 1900 N.E. 146th St., North Miami, Fla.

(Continued on page 82)



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CIRCLE 677 ON READER SERVICE CARD PAGE 105

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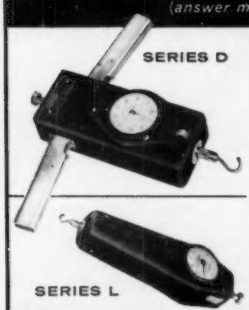

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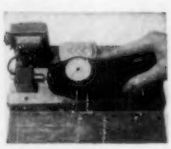

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Logan 1-0772

Illinois, Indiana
R. Edward Stemm
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Chicago 44, Ill.
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CIRCLE 679 ON READER SERVICE CARD PAGE 105

New Members

(*Continued from page 80*)

SOUTHERN CALIFORNIA DISTRICT (7)

Furane Plastics, Inc., John Delmonte, president, 4516 Brazil St., Los Angeles 39, Calif.

Fisher, Howard, R., chief chemist, W. J. Voit Rubber Corp., 1600 E. 25th St., Los Angeles 11, Calif.

Hoffmann, Harold J., quality engineer, Cannon Electric Co., 3208 Humboldt St., Los Angeles 31, Calif. For mail: 10614 Scott Ave., Whittier, Calif.

Pimbley, George H., research chemist, Turco Products, Inc., Box 2649 Terminal Annex, Los Angeles, Calif.

Shafter, Robert L., vice-president, sales, Automation Instruments, Inc., 401 E. Green St., Pasadena, Calif.

SOUTHWEST DISTRICT (16)

Lone Star Steel Co., L. G. Graper, vice-president, operations, research and development, Box 12226, Dallas 25, Tex.

Transcontinental Gas Pipe Line Corp., Mildred Hogan, librarian, Box 296, Houston 1, Tex.

Brown, William L., chief chemist, Ormet Corp., Box 177, Gonzales, La.

Salyer, B. M., Jr., president, Salyer Refining Co., Inc., Box 6115, Oklahoma City 11, Okla.

Weaver, Jack A., chemist, Columbian Carbon Co., 1100 N. 18th St., Monroe, La. [A]

WASHINGTON, D. C., DISTRICT (14)

Goode, Joseph F., highway physical research engineer, U. S. Bureau of Public Roads, Division of Physical Research, Washington 25, D. C.

WESTERN NEW YORK-ONTARIO DISTRICT (10)

Ewbank and Partners (Canada) Ltd., S. W. Fraser-Underhill, director and general manager, 200 Bloor St., E., Toronto 5, Ont., Canada.

U. S. AND POSSESSIONS

Long, Malcom G., president, Long Construction Co., Box 1875, Billings, Mont.

Stauffer, Clyde M., John E. Stephens and Associates, 603 N. 3rd Ave., Phoenix, Ariz.

U. S. Army Engineer District, Corps of Engineers, Librarian, Bldg. 608, City-County Airport, Walla Walla, Wash.

Williams, Hanen H., owner, Williams Engineering Co., 367 N. 5th Ave., Phoenix, Ariz.

Wright, P. L., superintendent, cement plant, Ash Grove Lime and Portland Cement Co., Louisville, Nebr.

OTHER THAN U. S. POSSESSIONS

Administracion de Ferrocarriles del Estado, Gerencia de Material and Tracción, Peñarol, Montevideo, Uruguay.

Armstrong Siddeley (Brockworth), Ltd., N. G. Griffiths, chief metallurgist, Hucclecote, Gloucester, England.

Canadian Erectors Manufacturing, Ltd., S. R. Hawkins, secretary-treasurer, 5441 Notre Dame St. W., Montreal, P. Q., Canada.

China Survey Co., Ltd., V. C. Lee, general manager, 43, Chang An (W) Rd., Taipei, Taiwan, British Colony.

Compañia Anonima de Concreto, John G. Dempsey, manager, c/o Shell Oil Co., Bachaquero, Estado Zulia, Venezuela.

Hardie and Coy, Pty., Ltd., James F. A. Page, chief engineer, Box 70, Parramatta, N. S. W., Australia.

K. K. Toyo Seiki Seisaku-sho, Torao Ojima, director, technical engineering dept., 15, Takinogawa, 5-chome, Kitaku, Tokyo, Japan.

Marley Tile (Holding) Co., Ltd., The, F. L. Brady, technical director, Riverhead, Sevenoaks, Kent, England.

(*Continued on page 84*)

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New Members

(*Continued from page 82*)

Bovet, H. J. S., assistant chief of lab., Swiss Metalworks Selve and Co., Scheibenstr, Thoune, Switzerland.

Danos, Peter, director, technical development, Minnesota de France, 135 Boulevard Sérurier, Paris 19ème, France.

McCarthy, Herbert Edward Alfred, Technical Building Materials, 60–64 Westbeach Rd., Keswick, South Australia.

Payet G., Guillermo, civil engineer and architect, Jiron Carabaya 959, Lima, Peru.

Ramirez Tellez, Alberto, chief, soils and concrete lab., Empresa de Acueducto y Alcantarillado de Bogota, Ave. Jiménez 4-90, Bogota, Colombia.

Van Vinckenroy, Victor, administrator-director, Centre D'Information du Cobalt, 35, rue des Colonies, Brussels, Belgium.

*A denotes Associate member.

DEATHS . . .

George Granger Brown, dean of The University of Michigan College of Engineering, Ann Arbor, Mich. (August 26, 1957). A member of the faculty since 1920, dean since 1951, and for many years professor and chairman of the department of chemical engineering, he was known internationally for his research and contributions to engineering education. In 1954 he was named to deliver the 30th annual Henry Russel Lecture, the University's highest professional recognition of academic and scientific competence. Regarded by fellow engineers as a pioneer in the fields of combustion and fractional distillation, Dean Brown had wide experience as a consultant and research director on the subjects of petroleum, natural gas, liquid fuel utilization, gaseous explosives, thermodynamics, and the clay and sand resources of Michigan. As dean of the College of Engineering he instituted educational programs designed to give engineering students greater understanding of the basic sciences. He also was a prime mover of the Industrial Program, a plan established in 1954 to open direct channels of communication between industry and the College of Engineering. Active in many professional and technical groups, he was a member of ASTM for more than 25 years and a contributor to the activities of Technical Committee A on Gasoline of Committee D-2 on Petroleum Products and Lubricants.

George A. Burrell, chairman of board, Burrell Corp., Pittsburgh, Pa. (August 16, 1957). A distinguished career ended with the passing of Colonel Burrell in New York City after a long illness. A graduate (chemical engineering) of Ohio State University, with an honorary doctor of science degree from Wesleyan University, Middletown, Conn., he was president of Burrell Corp. (laboratory apparatus firm) from 1923 to 1952, and chairman of the board from 1952 until his death. The company is represented in ASTM through the longtime membership of company president Guy H. Burrell, brother of the deceased. In charge of gas investigations for the U. S. Bureau of Mines 1908–1916, Colonel Burrell discovered helium supply in Texas and initiated the U. S. Government Helium Program in 1917; also helped initiate Chemical Warfare Service, U. S. Army, World War I, having charge of research work. He was the author of many technical articles and U. S. Government bulletins.

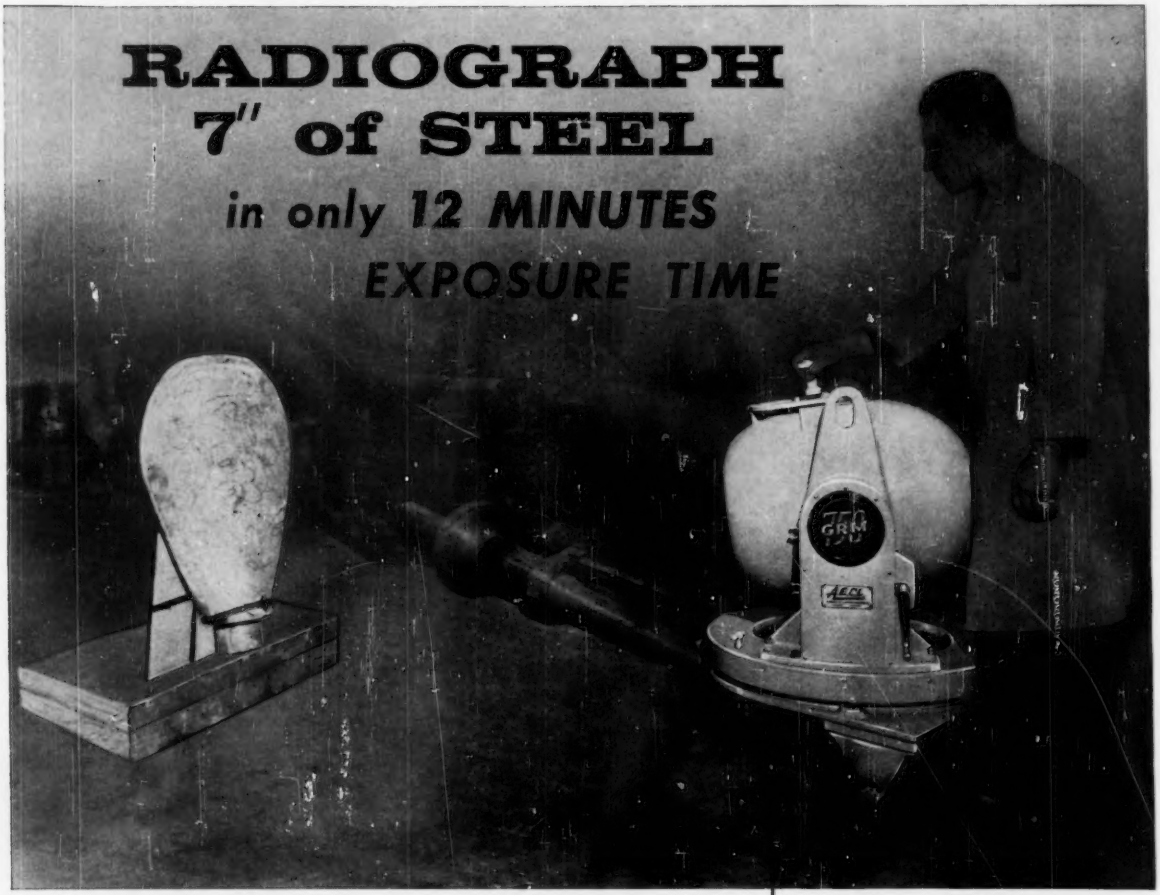
F. G. Campbell, chief engineer, Elgin, Joliet and Eastern Railway Co., Joliet, Ill. (1953). Representative of company membership since 1948.

Manvel C. Dailey, Kaiser Gypsum Co., Inc., Antioch, Calif. (July 11, 1957.) Representative of company membership since 1953, also member of Committee C-11 on Gypsum and its subcommittees concerned with plasters, structural products, and aggregates. Member of Northern California District Council since 1955.

T. McLean Jasper, consulting engineer, Milwaukee, Wis.; retired director of research, A. O. Smith Corp. (August 3, 1957). Member since 1924. Member of former Research Committee on Fatigue of Metals from 1928 to 1946.

Henry L. Kennedy, manager of cement division, Dewey and Almy Chemical Co., Cambridge, Mass.; residence, 69 Radcliffe Rd., Belmont, Mass. (September 10, 1957). A native of Medfield, Mass., and graduate of Wentworth Institute, Northeastern University, and Beaune University (France), with international experience in design of building structures,

(*Continued on page 86*)



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FOR FURTHER INFORMATION CIRCLE 683 ON READER SERVICE CARD PAGE 105

Deaths

(*Continued from page 84*)

Mr. Kennedy had been associated with Dewey & Almy Co. since 1932. Previously he practiced as consulting architect and engineer, and for a number of years headed the construction course at Wentworth Institute Evening School, also lectured on structural design at Franklin Technical Institute. More recently he had lectured on concrete technology at Harvard Graduate Engineering School. Mr. Kennedy represented the Dewey & Almy Co. membership in ASTM since 1935, and was very active in certain technical work of the Society, making valued contributions especially to the groups concerned with cement and concrete. Since 1944 he had headed the Subcommittee on Bleeding, Plasticity, and Workability of Committee C-1 on Cement; and worked also on other subcommittees. For some time prior to his death he had been serving as Vice-Chairman of Committee C-9 on Concrete and Concrete Aggregates, heading the Administration Group of C-9, and serving on several of the subcommittees. He was a member of the ASTM New England District Council 1949–1951. Other Society affiliations include the American Society of Civil Engineers, American Institute of Architects, and the American Concrete Institute (president, 1954). Respected and admired by co-workers and friends, Mr. Kennedy will be greatly missed by those associated with him in technical and other activities.

Albert MacLeod, chemical engineer, paint maintenance research, The Dow Chemical Co., Midland, Mich. (June 30, 1957). Member since 1951, serving on Committee D-1 on Paint, Varnish, Lacquer, and Related Products, and on the subcommittees concerned with accelerated tests for protective coatings, optical properties, shellac, physical properties, cellulosic coatings, and painting of metals. Mr. MacLeod also represented Committee D-1 on Committee C-15 on Manufactured Masonry Units and its Subcommittee V on Waterproofing Materials for Unit Masonry Walls.

R. C. Palmer, vice-president and chemical director, Newport Industries, Inc., Div. of Heyden Newport Chemical Corp., Pensacola, Fla. (June 12, 1957). Representative of company membership since 1925, serving through the entire period on Committee D-17 on Naval Stores, and Subcommittees I on Softening Point of Rosin, and IV on Chemical Analysis of Rosin, and the Special Subcommittee on Color.

H. E. White, Stone & Webster Engineering Corp., Boston, Mass. (1957). Representative of company since 1954 on Committee B-5 on Copper and Copper Alloys and its Subcommittee W-4 on Pipe and Tube.

Major Cobalt Producers Form Institute

At the first General Assembly of the Cobalt Development Inst., January 16, in Brussels, Belgium, the following officers were elected: M. Robiliart (Administrateur délègue of Union Miniere du Haut-Katanga), chairman of the Institute; E. C. Baring (director of the Rhokana Corp., Ltd.), vice-chairman; and Ch. Piedboeuf (chairman of the Centre d'Information du Cobalt), vice-chairman.

The Cobalt Development Inst. is a technical and scientific organization, made up of the world's major cobalt producers. Its object is to improve the existing uses of cobalt and to develop new ones. The Belgian limited liability company Centre d'Information du Cobalt has been entrusted with the execution of the Institute's program. The Centre is located in Brussels, at 35 rue des Colonies, and is represented in the United States by the Cobalt Information Center at the Battelle Memorial Inst. in Columbus, Ohio.

NEWS NOTES ON
Laboratory Supplies and Testing Equipment

Note—This information is based on literature and statements from apparatus manufacturers and laboratory supply houses. The Society is not responsible for statements advanced in this publication.

LABORATORY ITEMS

DC Amplifier—Model 307-A is a low-drift amplifier for use with wire strain gages, load, pressure and acceleration transducers, thermocouples, etc. It will drive most commercial galvanometers, including the low-sensitivity high-frequency types, and provides high gain with linearity over a wide range of input voltages.
Allegany Instrument Co., Inc. 1442

30,000 Volt DC Hypot—Model 5250 is the new portable bench type dc Hypot designed for testing HV insulation characteristics of electronic components and equipment, capacitors, plastics, other insulation materials, electrical equipment, power cables, etc., at voltages to 30 kv at 2.5 ma dc.
Associated Research, Inc. 1443

Aging Ovens—Designed specifically for certain ASTM tests involving accelerated aging at controlled temperatures for rubber plastics, textiles, insulations, roof coverings, varnishes and paints, Con-Wate Mechanical Convection Aging Oven with Power-O-Matic Control now available with a temperature range to 180 C.
Blue M Electric Co. 1444

Adsorbents—A complete line of adsorbents for gas and vapor-phase chromatography. Includes a comprehensive selection of ready-to-use partitioning agents and properly sized, solid adsorbents.
Burrell Corp. 1445

Fuel Test—A new instrument for the determination of the smoke point of a wide range of hydrocarbon fuels is a smoke point lamp, equipped with a chimney calibrated in millimeters, so that the smoke point of a sample under test can be read off directly.
Central Scientific Co. 1446

Torque Tester—Designed to test subfractional hp motors. With 3 sets of interchangeable springs, it has the following capacities: 0.100 in. oz, 0.500 in. oz., 2 in. oz. The dial is graduated from 0–100 in. in increments of 1.
John Chatillon & Sons 1447

Sampler—New design of the Denver Vezin Type Sampler incorporates a cylindrical housing resulting in a more compact unit and reducing costs. It is designed for sampling material continuously.
Denver Equipment Co. 1448

Micrometer for Compressible Material—A new Digital Read-out Automatic Electronic Micrometer is being manufactured for precision measurement of fragile or compressible nonconducting materials and parts.
J. W. Dice Co. 1449

Pressure Transducer—Newly developed pressure pickup, Model PT 45, incorporates compensation for sensitivity, zero balance, zero drift due to temperature,

(*Continued on page 90*)

PERMAFUSED PIGMENT IS FOREVER

MAN has told time by the sun's position for ages past. And the markings on our new etched-stem laboratory thermometers will last for ages to come.

The markings on these excellent mercury-filled thermometers have "Legibility That Lasts", because they're made with PERMAFUSED Pigment, which is *fused directly into the glass.* It becomes a part of the glass. The markings will last for the life of the instrument.

Here's what that means for you:

- You can read these thermometers as long as there's light!
- No solution you test will affect the markings —not even organic solvents— except liquids that destroy the glass itself!
- There's no danger of contaminating test solutions with dissolved pigments.

Every Taylor etched thermometer, ASTM, Plain, Armored or Pocket-Type is precision-built and expertly annealed for minimum breakage. The permanent accuracy of the Taylor laboratory thermometer you choose is assured by skilled workmanship and expert aging before pointing. National Bureau of Standards requirements are the basis of design of Taylor thermometers. Special designs are made to order for specific scientific, research and production purposes.

• • •

For further information about PERMAFUSED Pigments, and what they can mean to your laboratory, call your Taylor supplier or write for **Catalog L.** Taylor Instrument Companies, Rochester, N. Y., and Toronto, Canada.

Taylor Instruments MEAN ACCURACY FIRST

FOR FURTHER INFORMATION CIRCLE 687 ON READER SERVICE CARD PAGE 105

Lab News

(*Continued from page 88*)

sensitivity change due to temperature, input impedance, and output impedance.
Dynamic Instrument Co. 1450

Gases in Metals—The Serfass Gas Analyzer will handle hydrogen concentrations through the full range from 2000 ppm down to 0.1 ppm.
Fisher Scientific Co. 1451

High Temperature Testing—Now offered is equipment for tension testing at temperatures up to 2200 F.
Instron Engineering Corp. 1452

Mirror Galvanometer—A self-contained mirror galvanometer offering sensitivity as high as 2000 mm per microampere is now available.
Jarrell-Ash Co. 1453

Omni-Shaker—An all-purpose variable speed shaker, particularly useful in shaking stoppered test tubes and vessels under pressure, has been released with necessary clamps, tube-holders, and the specialized glassware, supplied.
Laboratory Glass and Instruments Corp. 1454

Sulfur Determinator—A new automatic sulfur determinator for simple, automatic sulfur titrations.
Lindberg Engineering Co. 1455

Altitude-Temperature Test—New low-cost system for simulating combined altitude and temperature environments, featuring a lift-out altitude chamber to provide separate altitude and temperature testing units.
Mantec, Inc. 1456

Analyzer—The 100-Channel Quartz Line Pulse Height Analyzer (Model PHA-2) makes use of a pulse-height-to-time converter unit (which eliminates the need for a large number of accurately biased discriminators), and an ultrasonic delay line memory, which replaces a large number of scaling circuits.
Nucleonic Corp. of America 1457

Parabar—A test unit that provides pressures to 30,000 atmospheres in a chamber $\frac{1}{2}$ in. in diameter by 10 in. high, is known as the Parabar.
Nucor Research, Inc., Very-High-Pressure Dept. 1458

Stirrer—New Morton Hi-Speed Stirrer, an apparatus for carrying out heterogeneous reactions with increased yields and greater reaction rates is driven by a 17,000 rpm $\frac{1}{5}$-hp, 115-v ac-dc motor using a variable voltage transformer for speed adjustment.
Scientific Equipment Corp. 1459

Creep Tester—A 12,000-lb creep-rupture testing machine that can be banked and run at the same load by a hydraulic load maintainer. Called Model RH-12, it has an 1800 F split furnace, sealed at the bottom to prevent stack effect.
Tatnall Measuring Systems Co. 1460

Stir-Plate—A magnetic stirring hot plate has been added to the line of TEMCO laboratory and industrial heating equipment.
Thermo Electric Mfg. Co. 1461

CATALOGS AND LITERATURE

Environmental Testing—High-speed service, accuracy, and complete facilities are the key notes of a new brochure describing the environmental test facilities.
Associated Testing Laboratories, Inc. 2303

Timers—A new line of time delay relays and sequence program switches is described in an Engineering Data Report, no. 5.
Automatic Timing and Controls, Inc. 2304

Pulse Generator—A new wide range pulse generator, Type 1006, is illustrated and described in a technical bulletin, recently released.
Burroughs Corp. 2305

Rotational Viscometer—*Brochure No. 33* describes the instrument used to evaluate brushability of paints.
Gardner Laboratory, Inc. 2306

Test Instruments Catalog—Newly issued, 24-page *Catalog B*, describes and illustrates the entire line of instruments for electronic control and measurements. Included are detailed design and performance specifications.
Keithley Instruments, Inc. 2307

(*Continued on page 92*)

determine the viscosity of asphalts, road oil and fuel oils at test temperatures from 100°F. to 475°F.

New from Emil Greiner! The High Temperature Saybolt Viscosimeter... ideal for determining the viscosity of asphalts, road oil and fuel oils at test temperatures from 100°F. to 475°F.

The bath is constructed in the form of a solid aluminum block equipped with high temperature sheath chromolox ring type and circular band type heaters. The aluminum block is adequately insulated with 1½" of rockwool to the attractively finished outer jacket. The top of the aluminum block is fitted with a transite asbestos cover. The aluminum block is drilled to accommodate two standard Saybolt viscosity tubes. All wires leading from the heaters run through upright supports to the lower control box which houses two three-heat switches, powerstat (variable heat control) and pilot light. The thermoregulator is of the sensitive bi-metal type operating a heavy duty relay on the intermittent heat circuit. Sensitivity of control at bath temperature of 450°F. is ± 1°F.

PRICE LIST

G19775	Viscosimeter, High Temperature, complete as described above but without viscosity tubes or accessories ..... each	550.00
G19780	Viscosimeter Tube, bronze body with stainless steel orifice, either Universal or Furol, specify which type required ..... each	52.50
G19800	Viscosimeter Tube, stainless steel body, stainless steel orifice, either Universal or Furol, specify which type required ..... each	85.00
G19801	Displacement Ring, stainless steel, for use in overflow gallery of viscosity tube when running viscosity tests on asphalt..... each	12.50
G9090	Viscosity flask, pyrex brand glass, capacity 60 ml each	1.75
G19935	Viscosity strainer, 100 mesh..... each	2.00
G19940	Atlantic type strainer with 50 mesh screen each	2.00

High Temperature Saybolt
VISCOSIMETER

Other high temperature thermometers can be furnished in addition, to the standard Saybolt viscosity thermometer. Write for information.

The EMIL GREINER Co.

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FOR FURTHER INFORMATION CIRCLE 690 ON READER SERVICE CARD PAGE 105

Catalogs

(*Continued from page 90*)

Testing Machines—A complete line of Super "L" hydraulic universal testing machines are described in revised *Bulletin 47*.

Tinius Olsen Testing Machine Co. 2308

X-Ray Techniques—A new 4-page folder, dealing with problems related to pulse height analyzers used in X-ray work, is available.

Philips Electronics, Inc. 2309

INSTRUMENT COMPANY NEWS

Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.—Appointment of E. J. Byrne as petroleum industry manager for the Industrial Div. of Minneapolis-Honeywell is announced by J. A. Robinson. Also, K. R. Knoblauch, who became associated with Honeywell in 1924, will devote full time to duties as chemical industry manager on a national basis.

The Warren Corp., Pittsburgh, Pa.—Warren Corp., manufacturers and designers of industrial laboratory equipment, hospital furniture, X-ray accessories, and photographic equipment, opened its new Lustra Line Div. plant at Clarion, Pa., in September.

The Bookshelf

(*Continued from page 65*)

which did result from baking was promoted by a redistribution and not an elimination of hydrogen from the steel.

Failure promoted by cadmium plating is affected by the experimental conditions and has been discussed at length in the report. In the hydrogen-bearing zone, a crack is initiated and then, depending on the experimental conditions, may propagate to failure of the cross-section through overloading. Crack development is apparently independent, in part, on the composition and is minimized by reduction in carbon content or by an increase in silicon content.

Both the sustained-load and bend tests are suitable tests for evaluation of hydrogen embrittlement in ultra-high strength steels. The rotating-beam fatigue test is a relatively insensitive test of hydrogen embrittlement, but it can be used to provide an excellent measure of the "static" notch strength of the steel.

Filler Metal Comparison Charts

AWS A5.0-57, American Welding Society, 33 W. 39th St., New York City; 23 pp.; $2.

THE AWS receives many inquiries regarding filler metals and their classifications (they are classified by a joint committee of the AWS and ASTM). The questions usually pertain to what classification a certain brand belongs in, whether it has the same classification as another brand, and who makes and distributes it. Although some manufacturers print charts showing this information, none are inclusive enough to cover all inquiries.

As a service to members and all others who use welding, the AWS has published a comprehensive group of charts showing the AWS-ASTM classifications and the filler metals, by brand name, that are in these classifications. Letters were sent to all known filler-metal firms requesting their aid in preparing these charts. This publication is the result of the replies received.

Proceedings, RILEM Symposium on Winter Concreting

Danish National Institute of Building Research, 20 Borgergade, Copenhagen K, Denmark; 1574 pp.; 65 D. kroner.

THE Danish National Institute of Building Research has announced the publication of the *Proceedings* from the RILEM Symposium on Winter Concreting held in Copenhagen in February, 1956. The symposium was divided into five sessions.

(*Continued on page 94*)

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The Amsler High Frequency Vibrophore is one of the latest products of this world-renowned manufacturer of physical testing equipment.

It determines the fatigue properties of practically any material under fluctuating and alternating tensile, compressive, shear or torsional stresses.

Simple specimens or test bars, sections of assembled structures or machine components can be tested.

Two sizes of machines cover the load range from 44 to 22,000 lbs. The Vibrophore uses the classic principle of resonance which permits frequencies up to 300 cycles per second while ensuring the accurate maintenance of stresses within 1% of magnitude and time constancy.

The resonance principle also allows convenient determination of other values, such as the damping characteristics of materials under working conditions, or the dynamic modulus of elasticity. Electric furnace and cold chamber attachments allow fatigue tests over a temperature range of −375 F to +1400 F.

Other items in the AMSLER program:

- Static testing machines for loads from 25 grams to 2,500,000 pounds.
- Complete line of fatigue testing machines for loads up to 220,000 pounds.
- Components to build your own testing plant for large structures and assemblies.
- Complete line of concrete testing equipment.
- Microtesting machines based on the AMSLER-CHEVENARD principle.

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The Bookshelf

(*Continued from page 92*)

OTS Research Reports

These reports, recently made available to the public, can be obtained from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Order by number.

Stress Relaxation and Dynamic Properties of Ethylene Polymers. PB 121924

The Oxidative Degradation of Polyethylene. PB 121682

Polymer Research. PB 121832

Viscoelastic Properties of High Polymers: Table of Stress-Relaxation Data. PB 121749

Research on Intermetallic Containers for Melting Titanium. PB 121948

The Preparation and Properties of Titanium Tetrabromide. PB 121542

Phase and Free Energy Relationships in the System Titanium-Zirconium-Oxygen. PB 121981

Tantalum Determination. PB 121819

Development of Lean-Alloy Chromium-Nickel Stainless Steels for High-Temperature Use. PB 121026

Heat Resistant Paints for Rocket Launchers. PB 121736

Research on Elevated Temperature Resistant Ceramic Structural Adhesives. Part 2. PB 121941

Temper Brittleness of Boron-Treated Steel. PB 121589

Development of Cast Iron-Base Alloys of Austenitic Type for High Heat-Resistance and Scale Resistance. PB 121950

Improved Fatigue Life of Formed Stainless Steel Hydraulic Tubing by Prestressing. PB 121969

Interrelation of Fatigue Cracking Damping and Notch Sensitivity. PB 131025

An Investigation of Intergranular Oxidation in Stainless Steels and High-Nickel Alloys. PB 121795

The Dynamic Stress Distribution Surrounding a Running Crack: A Photoelastic Analysis. PB 121987

Research on Effects of Prestraining and Notch Sharpness on the Notch Strength of Materials. PB 121782

Thermal Buckling. PB 121512

Corrosion Properties of Various Materials in High-Temperature Waters. PB 111963

Fundamental Studies of the Adhesion of Organic Materials to Metal Substrates. PB 121982

Evaluation of Approaches to the Study of the Physical Nature of Metallic Surfaces. PB 121971

Elevated Temperature Resistant Silicone Structural Adhesives for Metals. PB 131024

Design Properties of High-Strength Steels in the Presence of Stress Concentration. Part 1, PB 121847; Part 2, PB 121883

Physical and Chemical Laboratory Evaluation of Experimental Silicate Base High Temperature Hydraulic Fluids. Part 4, PB 131042

A Sonic Shear Method for Determination of Shear Breakdown on Hydraulic Fluids and Lubricating Oils. PB 131012

Hydrogen Contamination in Titanium and Titanium Alloys. Part 2, PB 121761; Part 3, PB 121786

The Influence of Hydrogen on Delayed Failure in Titanium Alloys. PB 121997

Adhesive for Composite Material Used in Printed Circuitry. PB 121960

The Effect of Various Heat Treatment Cycles upon the Mechanical Properties of Titanium Alloys with Various Interstitial Levels. PB 131009

Wear Studies with Titanium. PB 121885

The Effect of Microstructural Variables and Interstitial Elements on the Fatigue Behavior of Titanium and Commercial Alloys. PB 121972

Relaxation Behavior of Titanium Alloys. PB 121978

True Stress—True Strain Properties of Titanium and Titanium Alloys and Effect of Vacuum Annealing on the Impact Properties of Titanium and Titanium Alloys. PB 121833

Study of Ultra High Temperatures. PB 121928

Study of the Utilization of a Solar Furnace for High Temperature Research on Solids. PB 121930

A Quantitative Theory of Grain Boundary Movement and Recrystallization in Metals in the Presence of Impurities. PB 121484

Notch-Sensitivity of Heat-Resistant Alloys at Elevated Temperatures: Part 3, PB 121791

Improvement of the Impact Resistance of Cermets. PB 131093

Catalytic Effect of Titanium on the Oxidation Stability of Lubricants. PB 131106

OTHER SOCIETIES' EVENTS

November 2–8—**2nd World Metallurgical Congress and 39th National Metal Exposition and Congress,** Amerian Society for Metals, International Amphitheater, Chicago, Ill.

November 3–8—**Society for Nondestructive Testing,** 2nd International Conference on Nondestructive Testing, Hotel Morrison, Chicago, Ill.

November 4–6—**American Concrete Institute,** Regional Meeting, Ben Franklin Hotel, Seattle, Wash.

November 4–6—**National Paint, Varnish and Lacquer Assn.,** Annual Convention, Sheraton Park and Shoreham, Washington, D. C.

November 4–6—**AIME Institute of Metals Div.,** Morrison Hotel, Chicago, Ill.

November 6–8—**Society of Rheology,** Annual Meeting, Textile Research Institute, Princeton, N. J.

November 11–13—**Structural Clay Products Industry** Annual Convention, Greenbrier Hotel, White Sulphur Springs, W. Va.

November 13–15—**American Standards Assn.,** Annual Meeting and 8th National Conference on Standards, St. Francis Hotel, San Francisco, Calif.

November 13–16—**Society of Naval Architects and Marine Engineers,** 65th Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

November 13–17—**The Building Exhibition,** Olympia, London, England.

November 14–16—**American Assn. of Textile Chemists and Colorists,** National Convention, Hotel Statler, Boston, Mass.

November 14–16—**American Society of Refrigerating Engineers,** 44th Semiannual Meeting, Shoreland Hotel, Chicago, Ill.

November 18–21—**Conference on Magnetism and Magnetic Materials,** Joint sponsors: AIEE, American Physical Soc., AIME, IRE, Office of Naval Research; Hotel Sheraton-Park, Washington, D. C.

November 26—**Manufacturing Chemists' Assn.,** 7th Semiannual Meeting and Winter Conference, Statler Hotel, New York, N. Y.

December 1–6—**The American Society of Mechanical Engineers,** Annual Meeting, Statler Hotel, New York, N. Y.

December 2–5—**American Rocket Society,** Annual Meeting, Statler Hotel, New York, N. Y.

December 8–11—**American Institute of Chemical Engineers,** Annual Meeting, Conrad Hilton Hotel, Chicago, Ill.

December 15–18—**American Society of Agricultural Engineers,** Winter Meeting, Edgewater Beach Hotel, Chicago, Ill.

December 26–31—**American Assn. for the Advancement of Science,** 12th Annual Meeting, Claypool Hotel, Indianapolis, Ind.

1958

January 6–8—**4th National Symposium on Reliability in Quality Control in Electronics,** Joint sponsors: ASQC, IRE, AIEE, RETMA, AIA; Statler Hotel, Washington, D. C.

ACCURACY

IN TEST RESULTS

is greatly increased by positive control of specimen temperatures

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WEATHER-OMETER®

A constant volume of air at a controlled temperature in the heavily insulated cabinet, maintains uniform predetermined specimen temperatures regardless of variations in room conditions.

Automatic control of humidities up to dew point is available as optional equipment.

All automatic controls are located on the front panel of the Weather-Ometer directly above the door of the test chamber.

Both horizontal and vertical testing is available. Shallow containers are used for semi-liquid materials and vertical panels for solid materials.

Source of radiation is two Atlas enclosed violet carbon arcs.

Complete technical information on the DMC Model and other Weather-Ometers is contained in the new Weather-Ometer catalog. Copy on request.

FADE-OMETER®

The Atlas Fade-Ometer has world-wide acceptance as the standard machine for testing the action of sunlight on materials.

A wide range of industrial products are tested daily in Atlas Fade-Ometers to determine the deterioration of materials due to the action of sunlight.

From 21 to 126 samples, depending on size, can be simultaneously exposed to the light of the Atlas Enclosed Carbon Arc. Temperature is controlled automatically and humidity is furnished by evaporation from a constant water reservoir. Operation of the Fade-Ometer is completely automatic, permitting the machine to be left in continuous 24-hour operation.

The Carbon Arc Lamp in the Fade-Ometer is the closest known duplicate of sunlight, both as to intensity and spectral distribution.

If your product is subject to deterioration by sunlight our engineers, with over a quarter of a century of experience in predetermining the fading of materials, can help you.

Catalog with technical information on request

ATLAS ELECTRIC DEVICES COMPANY

4114 N. Ravenswood Ave., Chicago 13, Ill.

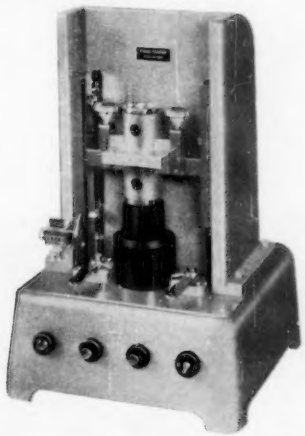
Manufacturers of accelerated testing equipment for over a quarter of a century.

CIRCLE 698 ON READER SERVICE CARD PAGE 105

DON'T BE LEFT HOLDING THE BAG!

measure its paper strength with the

frag-tester



A dynamic, rupture tester for paper and packaging materials which are subjected to energetic strain. A revolutionary new testing method which takes into account the gradual decrease of resistance to strain which widely influences the true usefulness of paper.

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Federal Government Standards Index Changes

THE General Services Administration of the Federal Supply Service is charged with the responsibility for establishing specifications to be used by the Federal Government for procurement of materials and supplies. The GSA issues an annual Index of Initiation of Federal Specifications Projects, and monthly supplements.

The items listed below appear in Supplements Nos. 3, 4, and 5 for the months of May, June, and July 1957.

INITIATIONS:

Title	Type of Action	Symbol or Number	FSC Code	FSSC Class	Assigned Agency and Preparing Activity
Adhesive, Vinyl Acetate Resin Emulsion	Rev.	MMM-A-00193 (GSA-FSS)	8090	52	GSA-FSS
Adhesive Water Resistant (Glue Mfgrs. Joint in Fiber-Boxes)	New	MM-A-200	8090	52	GSA-FSS
Aluminum Alloy 2011 (11S) Bars, Rods, and Wire (Free-Machinery)	Am. 1	QQ-A-365a	9530	..	GSA-FSS
Aluminum Alloy Bars, Rods, and Structural and Special Shaped Sections Extruded 6063 (63S)	New	..	9530 9540	..	DOD-Navy-Ships
Boxes, Paperboard, Metal-Stayed	New	PPP-B-665	8115	..	DOD-Navy-S&A
Bronze, Aluminum: Plate, Rolled Bar, Sheet and Strip	Rev.	QQ-B-667	..	..	DOD-Army-Ord.
Cable, Power, Electrical, Flexible Cord and Fixture Wire	Rev.	J-C-90a	6145	17	GSA-FSS
Calcium Chloride, Dihydrate, Technical and Calcium Chloride, Anhydrous, Technical	Rev.	O-C-105a & O-C-00105 (GSA-FSS)	6810	..	GSA-FSS
Cloth, Cotton, Broadcloth, Mercerized	New	CCC-C-437	8305	83	DOD-Army-QMC
Compound, Grease-Cleaning, Solvent-Emulsion Type	Am. 1	P-C-576a	6850	51	GSA-FSS
Copper Nickel Alloy Plate, Sheet, Strip and Rolled Bar	Am. 1	QQ-C-585	9530 9535	..	DOD
Copper Nickel Zinc Alloy Wire (other than Flat Wire)	New	Part of QQ-C-586	..	..	DOD-Army-Ord.
Copper, Nickel, Zinc, Alloy, Rods, Bars, Wires, Shapes, and Flat Wire	Rev.	QQ-C-586	9525	..	DOD-Army-Ord.
Copper Plates, Rolled Bars, Sheets, and Strips	Rev.	QQ-C-576a	..	..	DOD-Navy-Ships
Drums, 55-gallon, Light Weight	Rev.	PPP-D-711	8110	..	COM-BDSA
Hose, Gasoline, Rubber, Metal	Rev.	ZZ-H-466b	4720	..	DOD-Army-Ord.
Manganese Bronze Bars, Plates, Rods, Sheets, Strips, Flat Wire, Forgings Structural and Special Shaped Sections.	Rev.	QQ-M-80	..	..	DOD-Navy-Ships
Metals; Test Methods	Am. 1	Fed. Std. No. 151	..	..	DOD-Army-Ord.
Paperboard, Wrapping (With-Cushioning Value)	Rev.	PPP-P-00291 (Com-BDSA)	8135	..	COM-BDSA
Preservation, Packaging and Packing of Tapes, Paper, Gummed	New	PPP-P-681	8135	..	GSA-FSS
Rope; Mildew Resistant	Rev.	T-R-616a	4020	40	DOD-Navy-Ships
Sodium Phosphate, Tribasic Technical; Anhydrous Dodecahydrate and Monohydrate	Int. Am. 1	..	6810	51	GSA-FSS
Steel, Chemical Composition and Hardenability	Rev.	Fed. Std. No. 66	..	..	DOD
Stopcocks, Stoppers, and Joints; Ground Glass, Standard Taper	Rev.	DD-S-722c & DD-S-00722b (COM-BDSA)	..	..	COM-BDSA
Tape, Pressure-Sensitive Adhesive, Paper, Water-Resistant	Rev.	PPP-T-76	8135	..	DOD-Army-Ord.
Ties, Railroad, Wood (Cross and Switch)	Am. 1	MM-T-371b	..	..	DOD
Tires & Tubes (Inner), Pneumatic, Industrial	Rev.	ZZ-T-410	..	..	DOD-Army-Ord.
Zinc Plating (Electro-deposited)	Rev.	QQ-Z-325	8010	..	DOD

TITLE AND SYMBOL CHANGES:

Title	Type of Action	Symbol or Number	Former Title or Symbol
Anodes, Cadmium	Rev.	QQ-C-61	Cadmium, Anodes
Cable, Power, Electrical (Armored, Including Lead Cord) Covered Types and Armored	Rev.	J-C-71c	Cable, Armored (Including Lead Covered Types and Armored Cord.)
Cloth, Cotton, Buckram	New	CCC-C-438	Buckram; Cotton CCC-B-751
Cloth, Cotton, Jean, Bleached	New	CCC-C-444	Jean, Bleached CCC-J-191

WITHDRAWALS:

Title	Type of Action	Symbol or Number	Assigned Agency and Preparing Activity	Reason for Withdrawal
Calcium Chloride, Anhydrous, Technical	Rev.	O-C-104b & O-C-00104a (GSA-FSS)	GSA-FSS	Superseded by Int. Fed. Spec. O-C-00105 (GSA-FSS)
Calcium Chloride, Dihydrate, Technical	Rev.	O-C-106 & O-C-00106b (GSA-FSS)	GSA-FSS	Superseded by Int. Fed. Spec. O-C-00105 (GSA-FSS)

PROMULGATIONS:

Title	Type of Action	Symbol or Number
Alkali, Laundry, Containing Corboxymethyl Cellulose	New	P-A-450
Aluminum Alloy and Magnesium Alloy Wrought Products, Tolerances for	New	Fed. Std. No. 245
Asphalt; (For use in) Road and Pavement Construction	Am. 1	SS-A-706b
Boxes, Fiber (Superseding Fed. Spec. LLL-B-636c and LLL-B-631c)	New	PPP-B-636
Boxes, Wood, Cleated-Plywood (Superseding Fed. Spec. PPP-B-601)	Rev.	PPP-B-601a
Calcium Hypochlorite, Technical and Chlorinated Lime, Technical (Superseding Fed. Spec. O-C-114)	Rev.	O-C-114a
Cements, Hydraulic; Sampling, Inspection, and Testing	New	Fed. T. M. Std. 158
Cable, Power, Electrical (Flexible Cord and Fixture Wire) (Superseding Int. Fed. Spec. J-C-0090(GSA-FSS) & Fed. Spec. J-C-90)	Rev.	J-C-90a
Chromium Plating (Electrodeposited)	Am. 1	QQ-C-320
Cloth, Coated (Rubber and Plastic) and Plastic Sheeting (Rolls), for Hospital Use (Superseding Fed. Spec. ZZ-S-311a)	New	ZZ-C-450
Cloth, Cotton, Duck, Unbleached, Plied-Yarns-(Army and Numbered)	Am. 1	CCC-C-419
Cloth, Cotton, Sheeting (Laundry Cover Cloth) (Superseding Fed. Spec. CCC-B-276)	New	CCC-C-435
Cloth, Cotton, Drill (Superseding Fed. Spec.-CCC-D-651)	New	CCC-C-426
Compound, Grease-Cleaning, Solvent-Emulsion Type	Am. 1	P-C-576a
Copper-Nickel-Zinc-Alloy Rods, Bars, and Shapes	Am. 1	QQ-C-586
Creosote, Technical, Wood Preservative, (For) Brush, Spray, Open-Tank Treatment (Superseding Int. Fed. Spec. TT-W-00560a(GSA-FSS) & Fed. Spec. TT-W-560)	New	TT-C-655
Dipentene, Technical; (For use in Organic Protective Coatings) (Superseding Int. Fed Spec. TT-D-00376b (AGR-AMS) and Fed. Spec. TT-D-376a)	Rev.	TT-D-376c
Ethyl Alcohol (Ethanol); Denatured Alcohol; and Proprietary Solvent (Superseding Int. Fed. Spec. O-E-00760a (TR-IR) and Fed. Spec. O-E-760)	Rev.	O-E-760b
Filler, Wood, Paste (Superseding Fed. Spec., TT-F-336a)	Rev.	TT-F-336b

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(*Continued from page 98*)

PROMULGATIONS:

Title	Type of Action	Symbol or Number
Kerosine, Water-White, Deodorized (For Use in Insecticides) (Superseding Int. Fed. Spec. VV-S-00570(GSA-FSS))	New	VV-K-220
Lead; Pig (Superseding Int. Fed. Spec. QQ-L-00171b(Navy-Ships) and Fed. Spec. QQ-L-171a)	Rev.	QQ-L-171c
Metals: Test Methods	Int. Chg. Notice 1	Fed. Std. No. 151
Phosphor Bronze Bars, Plates, Rods, Sheets, Strips, Flat Wire, and Structural and Special Shaped Sections	Am. 1	QQ-P-330
Pigment, Indian Red and Bright Red (Iron Oxide),-Dry (For Use in Protective Coatings) (Superseding Int. Fed. Spec. TT-I-00511b (GSA-FSS) and Fed. TT-I-511a)	New	TT-P-375
Pigment, Lithopone, Dry (For Protective Coating) (Superseding Int. Fed. Spec. TT-L-00426a(GSA-FSS) and Fed. Spec. TT-L-426)	New	TT-P-400
Plastic Compounds, Molding, Cellulose Acetate Butyrate; and Molded or Extruded Parts	Am. 1	L-P-349a
Remover, Paint (Alkali-Type)	Am. 1	TT-R-230
Resin, Alkyd; Solutions	Am. 1	TT-R-266a
Rosin, Gum; Rosin, Wood; and Rosin, Tall Oil (Superseding Int. Fed. Spec. LLL-R-00626a (AGR-AMS) and Fed. Spec. LLL-R-626)	Rev.	LLL-R-626b
Soap, Grit (Hand, Paste and Powder) (Superseding Int. Fed. Spec. P-D-00221b(Navy-Ships) and Fed. Spec. P-D-221a)	New	P-S-577
Solder; Lead Alloy, Tin Lead Alloy, and Tin Alloy; Flux Cored Ribbon and Wire, and Solid Form (Superseding Fed. Spec. QQ-S-571b)	Rev.	QQ-S-571c
Soybean Oil (For Use in Organic Coatings) (Superseding Int. Fed. Spec. TT-O-0038a and Fed. Spec. TT-O-388)	New	TT-S-600
Steel Bars, Shapes, and Forgings Corrosion Resisting (Superseding Int. Fed. Spec. QQ-S-00763a (Navy-Ships) Fed. Spec. QQ-S-763a and Fed. Spec. QQ-S-766a (In part))	Rev.	QQ-S-763b
Tung Oil, Raw (China Wood) (For Use in Organic Coating) (Superseding Int. Fed. Spec. TT-O-00395a(AGR-AMS) and Fed. Spec. TT-O-395)	New	TT-T-775

INTERIM FEDERAL SPECIFICATIONS AND STANDARDS ISSUED:

Title	Type of Action	Symbol or Number
Adhesive, Animal Gelatin	Am. 1 to F.S.	MMM-A-100 (GSA-FSS)
Adhesive, Vinyl Acetate Resin Emulsion	Rev.	MMM-A-00193 (GSA-FSS)
Calcium Chloride, Dihydrate and Calcium Chloride, Anhydrous; Technical	Rev.	O-C-00105
Cushioning Material, Cellulosic	Am. 2 to F.S.	PPP-C-843 (GSA-FSS)
Drums, Metal, Reconditioned 55-Gallon (For Shipment of Noncorrosive Material)	Rev. 1	PPP-D-00732 (COM-BDSA)
Methyl Ethyl Ketone (For use in organic coatings)	New	TT-M-00261a
Mineral-Red (Iron-Oxide), Natural: Dry (Paint-Pigments)	Rev. of F.S.	TT-M-00381a (GSA-FSS)
Paint, Exterior, Fire-Retardant (White and Light Tints)	New	TT-P-0034 (Army-CE)
Plastic Sheet, Laminated (Thermosetting Resin)	New	L-P-00508 (GSA-FSS)
Soap, Toilet (Floating, White)	New	Int. Fed. Std. 0010a (GSA-FSS)
Sodium, Phosphate, Tribasic, Technical; Anhydrous, Dodecahydrate and Monohydrate	Am. 1	O-S-642
Tape: Pressure-Sensitive Adhesive, Filament Reinforced	New	PPP-T-0097b (COM-BDSA)
Varnish, Spar, Phenolic-Resin	Am. 1 to F.S.	TT-V-119 (GSA-FSS)

CANCELLATIONS:

Title	Symbol or Number	Reason for Cancellation
Boxes; Fiber Corrugated (For Domestic Shipment)	LLL-B-631c	Cancelled
Boxes, Fiber, Solid (For Domestic Shipment)	LLL-B-636c	Cancelled

(*Continued on page 102*)

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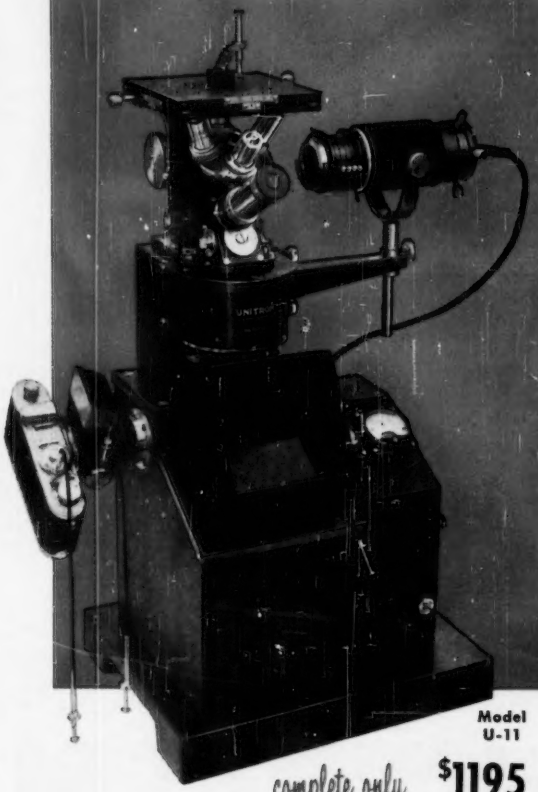

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- Calibrated square mechanical stage with calibrated rotatable stage plate.
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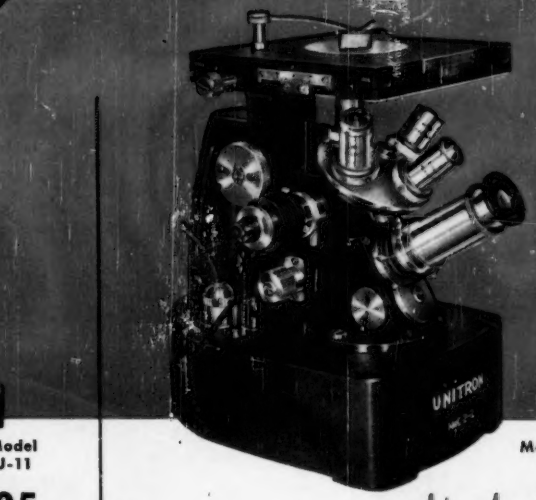
- Additional accessories, available at extra cost include: Polaroid Land Camera attachment for "60-second" photography; 35mm camera attachment; low power (5-40X) objectives; vacuum heating stage for temperatures to 1100°C.



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- Binocular model has provision for attaching 35mm camera to microscope base. A 35mm camera attachment is available to attach to the eyepiece tube of the monocular model.
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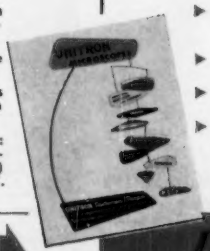

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CANCELLATIONS:

Title	Symbol or Number	Reason for Cancellation
Cements, Hydraulic Methods for Sampling, Inspection and Testing	SS-C-158	Cancelled
Detergents, Hand; Paste and Powder, For Mechanics' Use	P-D-221a	Cancelled
Fluid, Hydraulic Brake	VV-F-451a	Superseded by Fed. Spec. VV-H-910
Indian-Red and Bright-Red (Iron-Oxide); Dry (Paint Pigments)	TT-I-511a	Superseded by Fed. Spec. TT-P-365
Lithopone; Dry (Paint-Pigment)	TT-L-426	Superseded by Fed. Spec. TT-P-400
Nickel; Anodes	QQ-N-265	Superseded by Fed. Spec. QQ-A-677
Oil; Soybean Refined (For Use in Organic Coatings)	TT-O-388	Superseded by Fed. Spec. TT-S-600
Oil; Tung (China-Wood), Raw (For use in organic coatings)	TT-O-395	Superseded by Fed. Spec. TT-T-775
Sheeting; Rubber	ZZ-S-311a	Superseded by Fed. Spec. ZZ-C-450
Wood-Preservative; Coal-Tar-Creosote (Crystal-Free), (For) Brush, Spray, or Open-Tank Treatment	TT-W-560	Superseded by Fed. Spec. TT-W-500

SPECIFICATIONS AND STANDARDS APPROVED FOR PRINTING:

Title	Type of Action	Symbol or Number
Cements, Hydraulic; Sampling, Inspection and Testing	New	Fed. Std. No. 158
Cable, Power, Electrical (Flexible Cord and Fixture Wire)	New	I-C-90a
Compound, Grease-Cleaning, Solvent Emulsion Type	Am. 1	P-C-576a
Detergents, Hand; Paste and Powder, for Mechanics' Use	Canc.	P-D-221a
Soap, Grit (Hand, Paste and Powder)	New	P-S-577
Lead; Pig	Rev.	QQ-L-171c
Solder; Lead Alloy, Tin Lead Alloy, and Tin Alloy; Flux Cored Ribbon and Wire, and Solid Form	Rev.	QQ-S-571c
Asphalt; (For Use In) Road and Pavement Construction	Am. 1	SS-A-706b
Cements, Hydraulic Methods For Sampling, Inspection and Testing	Canc.	SS-C-158c
Creosote, Technical, Wood Preservative, (For) Brush, Spray, or Open-Tank Treatment	New	TT-C-655

SPECIFICATIONS AND STANDARDS APPROVED FOR PRINTING:

Title	Type of Action	Symbol or Number
Dipentene, Technical; (For Use In) Organic Protective Coatings	Rev.	TT-D-376c
Filler, Wood, Paste	Rev.	TT-F-336b
Ink, Marking Stencil, Opaque, For Nonporous Surfaces (Metals, Glass, Etc.)	Rev.	TT-I-558b
Ink, Marking Stencil, Opaque, For Porous Surfaces (Wood Boxes, Fiber Cartons, Etc.)	Rev.	TT-I-559b
Oil; Tung (China-Wood), Raw (For Use in Organic Coatings)	Canc.	TT-O-395
Resin, Alkyd; Solutions	Am. 1	TT-R-266a
Wood-Preservative; Coal-Tar-Creosote (Crystal-Free), (For) Brush, Spray, or Open-Tank Treatment	Canc.	TT-W-560
Kerosine, Water-White, Deodorized (For Use In Insecticides)	New	VV-K-220
Cloth, Coated (Rubber and Plastic) and Plastic Sheeting (Rolls), For Hospital Use	New	ZZ-C-450
Hose, Rubber, Steam	Rev.	ZZ-H-541b
Sheeting; Rubber	Canc.	ZZ-S-311a
Sheeting; Cotton, Laundry (Cover-Cloth)	Canc.	CCC-S-276
Boxes, Wood, Cleated-Plywood	New	PPP-B-601a
1,1,1-Trichloroethane, Technical, Inhibited (Methyl Chloroform)	New	620a
Glass Cleaner, Powder	New	P-G-411
Powder; Scouring (For) Highly Polished Glass	Canc.	P-P-596a
Soap, Toilet, Powdered, For use in dispensers	Rev.	P-S-626e
Bars; Reinforcement, (For) Concrete	Canc.	QQ-B-71a
Brass; Castings, Leaded Yellow	Rev.	QQ-B-621b
Steel Bar, Reinforcing (For) Concrete	New	QQ-S-632
Zinc; Sheet and Strip	Rev.	QQ-Z-301b
Sodium Chloride, Technical, For Water Softening Units	New	SS-S-550
Ethyl Acetate, Technical, Organic Coatings Use	Rev.	TT-E-751a
Indian-Red and Bright-Red (Iron-Oxide); Dry (Paint Pigments)	Canc.	TT-I-511a
Paper, Wrapping, Tissue	New	UU-P-553a
Pipe, Steel (Seamless and Welded (For Ordinary Use))	Rev.	WW-P-406a
Hose, Rubber; Windshield Wiper	Rev.	ZZ-H-617a
Bags: Textile, Shipping, Burlap, Cotton and Waterproof Laminated	New	PPP-B-35
Sacks, Shipping, Paper, Reinforced	New	PPP-S-50a

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